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HIGHWAY LOCATION and SURVEYING

BY

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F., A. A. S.; F., R. S. A.; Mem. Am. Soc. C. E., etc.

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Technical Publishers
221 EAST 20th ST.
CHICAGO, ILL.

E. & F. N. SPON, LTD.
57 Haymarket
London, England

TECHNICAL PUBLISHERS
221 East 20th Street
Chicago, Ill.

To

THE FATHER OF AMERICAN ROAD IMPROVEMENT

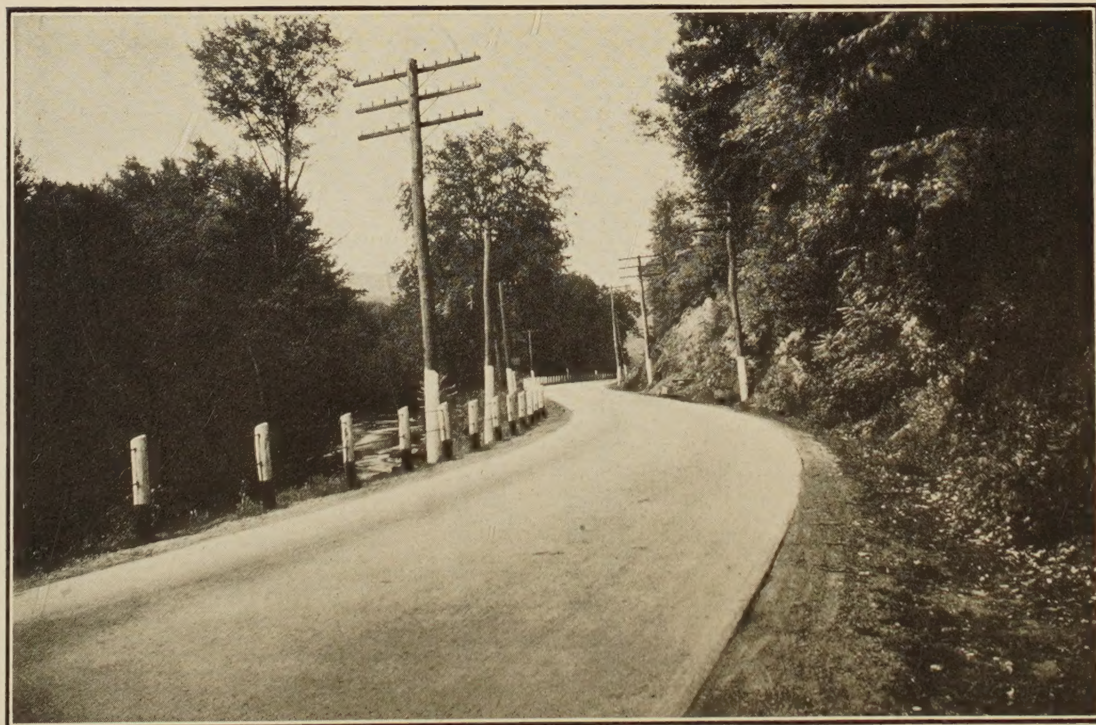
HON. WILLIAM E. McCLINTOCK

of

Chelsea, Massachusetts,

with his permission, this work is reverently dedicated.

engineering



Pleasing Location to Fit Local Conditions

INTRODUCTION

WHEN one goes to repainting or repairing or what is known as "doing over" a substantial old house, it is frequently found that some of the structure needs renewing or even rearranging to get away from defects or objections that contributed to or prompted the decision to attempt the more superficial work originally. And, also, the opportunity evidently so offered is seized to secure more extensive satisfaction with the final results.

But usually the costs mount, and one resolves then to avoid the same or similar fundamental errors "if ever a new house is undertaken."

So it has seemed to the writer, after many years of experience in the construction and maintenance of highway surfaces, now perhaps worth while to try to point out some of the underlying "structural" defects more or less generally to be found in highway systems.

And, in order to help constructively by contributing to the discussion of the subject and offering suggestions from his own knowledge and experience, he has added thereto the valuable contributions of such others as seemed most pertinent and appropriate in this connection.

BOOK ONE is intended to stimulate the "imagination" needed by "the successful locator" (p. 287). Its writing was begun more than five years ago. Possibly some of its ideas will now seem to many less novel than they were when first expressed. However, it is believed that their accentuation or repetition now may not be inadvisable.

BOOK TWO shows the "high lights" of the general subject as well as furnishing practical information of great value to all.

BOOK THREE is a compilation of practice, which, with the APPENDICES containing the Forms in actual use in one or more of the largest (in highway expenditures) states, shows the ways and means for translating theories into results.

So it is hoped that the whole may prove a contribution to the general welfare.

W. W. C.

Coronado, California,
August 5, 1929.

BOOK I

Notes on Highway Location

BY

W. W. CROSBY

B.C.E., C.E., D.Sc., D.Eng.

F., A. A. S.; F., R. S. A.; Mem. Am. Soc. C. E., etc.

FOREWORD

THIS part is not intended to be a text book nor even perhaps a reference book for road-builders. It may be well, also, to warn the reader now that certain omissions may become apparent. Most of them are intentional.

While it may be argued that the character of the pavement or surfacing of the roadway can affect the problems of location, the connection of the two does not seem sufficient to warrant, for all present purposes, the inclusion of surfacing considerations in this treatise. Also, ordinary drainage matters, such as affect particularly the construction and maintenance of the roadway, will not be regarded as influencing the problems of location, although the location may involve, immediately, problems of drainage for solution. Major drainage problems often involve special problems of location but in all other location work the questions of drainage will be regarded as factors to be cared for by construction rather than by location.

All location may be found to be surrounded by a kaleidoscopic variety of conditions, and it will evidently be impracticable even to attempt to discuss more than a generally representative set of postulated circumstances. Eccentric problems must be regarded as such and will be referred to hereafter only for illustrative purposes.

On the other hand, it appears desirable that a thorough understanding shall be had, by those seeking proper solutions of questions of highway location, of the past, present, and future of the circumstances now limiting or affecting the solutions.

In the attempts that must be made to foresee probable developments, and in order that durability of satisfaction with

a solution may be expected, it will first be necessary to look back along the line of development coming up to the present situation. With an understanding of this past origin and growth, a comprehensive study of the present situation may then be made in any case and, probably, a solution obtained which will give reasonable satisfaction today. The question then promptly arises as to what the prospects are for tomorrow. Alterations in conditions in the future must be estimated from the present facts and the changes that have occurred in the past, with a recognition of the influences that have brought them about. The influences of the future must be conceived rationally, and speculations as to future influences and conditions should be made conservatively in order, if possible, to insure as far ahead as practicable the life of the general satisfaction with today's solutions of the problems.

It should be remembered, however, that accomplishments are what is wanted on this line as on so many others, and that speculation (or estimation) spun out too long and too fine is precarious. In highway location also, applies that excellent definition of a good executive—"one who decides promptly and is sometimes right." But the Spanish proverb should be remembered—*"Quien adelante no mira, atras se queda."*

Thirty years ago the larger part of a state highway commission's (or engineer's) work was educational—bringing to the attention of the public the desirability of better road surfaces and convincing the taxpayers and voters of the advantages of spending more money or using the funds more scientifically for more durable and economical results on the roads and for general individual and community benefit.

There is a tendency now to present the work of highway authorities as entirely of service, which is, of course, correct enough if by service we fully recognize the breadth of the term. But the need for leadership, based on knowledge and ability, and for education of the non-expert voter and taxpayer in highway engineering developments still remains as

an important if not a large fraction of the whole duties of the head of a state highway department.

It may be granted that all of the problems herein to be discussed can be considered as covered by the head of "Relocations." Even the location now of an entirely new road between any two points of the inhabited world can be viewed as a relocation, because some sort of route already exists between the points mentioned and the new one is proposed only to secure another better in some respects.

From its inception, the suggestion of a relocation for a highway involves a regard for the existing road or routes between the same termini. Dissatisfaction with what is breeds the idea of relocation. But what is must itself have sprung from a cause. The farther back that cause—and thus, usually, the more obscure it may be—the greater should be the regard and search for it in order to make sure that it no longer exists, or at least that, if it does, the needs of it will continue to be satisfied by the relocation proposed for other and newer reasons. "The God of Things as They Are" should be given due consideration before cleaning up the sacrificial offerings before him.

"Whatever is" may not now be "best," but it is fairly certain there will be found one or more good reasons for its existence. Before determining, therefore, to make an alteration or serious relocation of a well established highway—particularly one along any questionable section of which developments are well established—it will be well to regard the facts underlying the present location, as well as the possibilities of the relocation, suggested for certain reasons, and to compare the weight of the reasons behind each as well as the advantages from various viewpoints of the alternative lines. Possibly changed conditions warrant different consideration and relocated lines for the highway, but it may be, on the other hand, that they do not. The shortest highway between two points does not always render the greatest social service nor is the "Race" (of the location)—for good to the

public "to the Swift" (over short, straight lines and minimum grades).

Disturbance, to the point of serious dislocation, of long established transportation routes and conditions must be carefully regarded before determined upon for theoretical benefits to estimated future traffic.

"Excepting possibly the inventors of the alphabet and the printing press, the greatest benefactors of mankind are those who have improved the means of communication."* Ways of physical communication between individuals or communities of the human race are necessary, and the need increases with civilization and development. With the latter the value of time increases or becomes more apparent. Hence directness of a highway receives an emphasis, sometimes to the point of distortion. For, as civilization and culture advance, it is recognized that time is not only provided for work, but also for enjoyment of life. As the standards of living rise, pleasures make their demands for consideration beside those of gain. And then, later, it usually becomes evident that the enjoyment of Nature is one of the greatest of real pleasures.

Therefore, it may rationally be concluded that in highway location time-saving (by directness, i. e., straightness) has in many cases a limit not to be exceeded if the other and broader functions of the highway are to be given the proper consideration that modern tendencies of life—perhaps particularly in these United States—seem to demand.

It can generally be assumed that the old location has now practically no scientific foundation. Hence, if there seem to be weighty reasons for seeking a better location one may start out on scientific lines and be almost sure of finding at least one relocation for the road in question that will offer advantages over the existing road. Generally speaking, the weakest points of the old locations now seem to be their indirectness between distant termini, or their extreme curvature between nearer points, and their excessive grades.

*Adam Smith in "The Wealth of Nations."

As has been suggested, reasons for these present defects existed and may still persist in the broader view and for some of the larger considerations. Indirectness may mean service and general good when directness may mean theoretical good to a limited few. The questions of allowable grades now and tomorrow are by no means near solution even though we know that the natural laws of this existence demand the expenditure of energy to overcome gravity. And we, in this connection, do not know much more than that yet.

Most road problems begin at the surface, and even now, in the larger number at least, seem to concern only the roadway surface. But like a pathologist worthy of that name, the engineer should look deeper for remedies of the disease and not merely for palliatives of the symptoms. Analysis through the evident symptoms is necessary for the discovery of the real trouble.

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Notes on Highway Location

CHAPTER I

GENERAL

"Glittering generalities! They are blazing ubiquities."
—Emerson.

A HIGHWAY location involves not only the three dimensions of space, but also consideration at least of a possible fourth. It has been well said: "All our knowledge of location (or speed) is relative, so that time becomes practically a fourth dimension."

The use of the highway, i. e., the character and speed of the traffic for which it is provided, will affect the location materially, and it may be possible that even the directional speed of the majority traffic will affect solutions of location questions in the dimensions first mentioned.

Let it first be understood that a highway location has, of course, length. It must also have breadth. And it has thickness if we regard, for convenience, the profile of the highway as occupying that third dimension.

"Highway" is used herein to embrace all public rights of way provided for pedestrian and vehicular traffic other than that carried by rails alone, but a highway may contain rails or tracks for use by special vehicles. The customary terms, "railways" or "tracks," will apply to such structures. For further reference to the precise meanings in case of doubt see Trans. American Society of Civil Engineers, Vol. LXXXII (1918), p. 1420.

The science of highway location includes the comprehension of the recognized mathematical principles that affect its

problems; the application of established formulae; and the rational development of new formulae for the mathematical solution, where possible, of these problems; the reduction, by logical methods just so far as practicable, of indefinite factors in the equations, to numerical values; the substitution of figures for opinions or prejudices. And the mathematical translation of the different forces or influences at work to affect the decision into a resultant clearly defined in economic terms means scientific work or methods.

While it is entirely probable that neither the present needs nor the developments to date in the science of highway engineering permit the solution of many problems of highway location solely by scientific methods, yet it is inescapably true that the scientific means of approach to such problems is far preferable to any other treatment of them if equitable, economic, and durably satisfactory physical results are to be insured.

Further, the Art of highway location must, to produce such results, rest on scientific bases or principles, no matter how much the scientific equations or solutions may involve factors that are not arithmetical and are even psychological.

The art of highway location may be regarded as the execution of the work, both in the office and in the field, of fixing graphically or physically the location of the highway in the three dimensions of space. The art may even merge into the solution of scientific equations and there apply to the establishment of values for certain variables or indeterminates. Or it may comprehend cunning adjustments of scientific conclusions to incalculable, even inexpressible, but none the less actual, circumstances or forces to be found in the field and their translation into economic results. Between these margins lies a wide field of art.

Many have had experience or noticed the effects in house construction of a lack of skill in the plans. The construction itself may be excellent when instead of a competent architect a "practical builder" is turned loose and authorized to com-

plete the house on plans prepared in his (the contractor's) office and under the general approval of the owner, who himself is not an artist nor a man trained in such matters. The results may often appear economical, generally convenient, substantial, and satisfactory along the lines of everyday use of the house. But almost always there come dissatisfaction and disappointments as to some deficiencies in appearance and in the completeness or suitability of the structure, that grow as time goes by and as developments occur, which regrets can then be seen to be due to the failure to secure advice in season from a competent party trained to vision ahead and to regard for what is too often considered by many as an aesthetic and even impractical view of material affairs.

Is not the same consideration now due road location (and construction thereon) as to home building?

This art, or application of the science, while based on the understanding of the science and a clear recognition of its character, development and possibilities, involves the translation of those principles into material results for physical use. The fundamental science is, and for a long time will be, clear only in part. In every problem or equation there will be present factors, on one or both sides, for which no science will enable the substitution of positive and exact values. Here the opportunity for art to apply its education, training experience, and skill is offered. And when the equation shall be resolved to an "answer" then the translation into results of that answer successfully, or not, depends entirely upon the degree and character of the art employed.

Art, even when descended from science and inheriting certain attributes or functions, still remains in its development powerfully affected by environment. Practice perfects it, but the parentage must not be overlooked.

CHAPTER II

HISTORICAL

"I have but one lamp by which my feet are guided, and that is the lamp of experience. I know no way of judging of the future but by the past."

—*Patrick Henry* (1775).

GOOD roadways are concomitants of maturity in countries or their subdivisions. Their existence implies, further, a considerable degree of education, civilization and prosperity. Good highways—well located roadways as well as suitably surfaced ones—testify either to advanced maturity or to extraordinary precocity and virility of youth, but, also, in both cases to higher education, development and civilization.

Rome, at her summit of prosperity and power, located (and built durably surfaced) highways—not for sake of individuals nor for the sake of votes to candidates for elective offices, but for meeting the needs of imperial government.

Napoleon, in his day, followed for France the example thus set, and in England and a few of the older, highly developed, and civilized countries there may be found more or less evidence of highway location from the broader points of view.

In the United States, highway location has until recently been very largely from selfish and narrow political conceptions.

Any one tracing the growth of the public road system of these United States can but be convinced of this. The first settlers connected their dwellings with paths which have become streets. The first settlements tied themselves together with roads which have become main highways. As the settle-

ments pushed westward and the country generally became more thickly occupied, the growth of the road system proceeded mainly on the same basis. Connections were made between individuals or small groups of individuals in their interests and for the means of locomotion then available—that is, for pedestrians, horseback riders and slow-moving animal drawn vehicles. Relatively little change in the original routes cleared through the forests, or marked across the plains towards feasible crossing of the streams and of the mountains, took place between the first use of the route as a foot path and the later improvement and use of the route as a roadway. With the establishment of the routes came the settlement of the lands along them and, thus, the further determination of the location of the existing roads.

Possibly an exception to the foregoing general statements should be noted. Some of the roads connecting settlements were built as toll roads, and in these cases usually the rudiments of scientific location were evidenced by such charter requirements as limited the length, breadth, or grades.

As the importance of means of inter-communication, particularly between centers of population, increased, mathematical considerations entered more and more to influence the lines and grades of them. And as the communities organized into states and the nation itself began to recognize the community of interest in the public roads and to assume the responsibility for at least the main roads, location questions began to crystallize in forms, similar in some ways, at least, to those of the present time.

Originally the interest and responsibility rested with a few individuals. That individual interest still remains and always will persist. But, as the individual interest in other matters inevitably became subsidiary to the community interest, so the location of the highways from house to house and along property lines—where each owner gave one-half the right-of-way necessary for the road, or, in order to avoid damage to an individual farm land, the road location was detoured through

less valuable land—that location became a matter in which were vitally interested a far larger number of people than those simply owning the land or living directly on the roadside.

The defective locations, from the larger point of view, of some of these older roads impelled communities or states to construct new roads more directly located and thus of greater general public convenience and value. After the union of the separate states the more general interest in the public highway was evidenced by the improvement of inter-state roads and indeed by provisions through the national congress for national roads.

In these broader conceptions some of the primary features of highway location have been manifest. For instance, in the act of Congress in 1806 a national highway was ordered surveyed and built from Cumberland on the Potomac river, at the head of the canal from Atlantic tide water, to Wheeling on the Ohio River, then the head of navigation down the Ohio and the Mississippi to the Gulf of Mexico. In this act it was provided that the road should have no grade exceeding five degrees from the horizontal.

In later years, when the national government undertook the development of its flat western lands, a geometrical system of highway location was adopted. But it may be questioned if the rectangular systems of highways established by the government in some western states were based on anything broader than local considerations.

When the development of the public roads of the United States—more particularly, perhaps, that of the more important or through roads, i. e., roads of considerable length connecting important centers relatively far apart, or inter-state roads—was interrupted by the developments of steam railroad construction, the broader conceptions as to the location of highways wilted and practically became dormant. The growth of the public road system went on, but the matter of location

Fig. 1. Example of poor location because of obvious indirectness and lack of apparent good reason for the latter.

reverted to the bases of local or individual interest, and of politics.

About thirty years ago there had sprung up in some of the more progressive states a general public desire for better road surfaces, and modern highway work was begun in this country. By that time the public road systems of most of the states had grown to reach mileage figures, most of them unwieldy and to some extent unnecessarily high. To satisfy the first demands for "all the year roads" required large expenditures, according to the ideas of the times, and it soon became generally accepted that a selection from the existing mileage would have to be made to keep within the means of the state and to produce the results needed. So the problem of selection became evidently a primary problem of highway location, in the broader sense, and it opened wide the door for political influence.

Naturally every inhabitant of the country wanted the

improved roads to accommodate him, and, equally, every community wanted the main highway to serve it. In the earlier stages of the legislation the acts were confined to the improvement of the existing roads, and the state authorities, to whom the administration of the law and the execution of the work was delegated, were given little, if any, opportunities to consider and effect changes of existing highway locations with a view to improvements in them for the general benefit.

In some of the states the initiative for the selection of the roadways to be improved was left with the local or county authorities, and where the local or county interest did not accord with the more general public interest a deadlock resulted. In some other states the legislature provided commissions for the selection of limited mileages of the existing public roads, which selected roads were to be improved by the states, but no provision was made for the consideration of new locations. In other states, of which possibly the most noted examples are New York and Pennsylvania, the selections from the existing public roads were made by the legislators themselves.

It can be readily appreciated from the foregoing that the opportunities for and the probabilities of selfish and political influence seriously affected the selection—that is, the location—of the routes of the state highway system established in this way. As a matter of fact, many more routes were proposed than were established by the act and compromises in the legislatures were numerous. In these states, since the original establishment of the state highway system, those dissatisfied with it have with more or less success continuously attempted to modify or to add to the original selection (or location) by additional routes similarly described. In a legislative session of New York State recently, the political influence for modification of the existing state highway system succeeded in passing an act through legislature which was vetoed by Governor Smith, and his veto message embraced the following phrases in comment on the legislative act. He referred to the

addition or modified routings as "laid out as a matter of political favor" and as comprising "dead end roads," "parallel roads," "roads in sparsely settled sections." He further expressed himself to the effect that road location was "not a legislative function," but that it was "administrative and best carried out by the state's engineers."

Commenting on and supporting Governor Smith's action the *Engineering News-Record* for May 15, 1924, said editorially in regard to road location that "only trained officials may assume to undertake the solution."

Here we have, for the first time, perhaps, clear recognition by high authorities of the scientific basis on which road location—which, of course, involves selection—should rest.

Another state nearly twenty years ago approached her location problem—that is, the selection of a limited mileage from the total mileage of public roads in the state—by the legislative creation of a commission authorized and directed "to select such a system of main market roads in and throughout the state as could reasonably be expected to be improved with the funds provided," ($5,000,000). Again note the limitation, by the word "select," to the then located roads and the absence of even any suggestion, to say nothing of authority, for revising the existing locations from scientific standpoints. In spite of the fact that the average cost of road improvement per mile in the state to that time had been kept down to $8,000 per mile and even if estimated at $5,000 per mile would have permitted the selection of less than 1,000 miles for the state system at the maximum, the commission, composed of four professional politicians, two scientists and a business man, selected over 1,200 miles of the existing roads as a "system" under the act.

This was done by the politicians referred to despite the protests of the scientists and the business man. Since that original establishment, several hundred more miles of road have been added to the state system by legislative act, i. e., by political location.

The instances above cited are brought forward not as horrible examples, but as reasonably fair illustrations of how road location has, up to the present time, and generally, been based, as first stated, on other than scientific fundamentals.

In the Pennsylvania law, however, appears the first real recognition of the fact that other bases than those of political and selfish interest may affect the location of highways. That law provides, in a section subsequent to those establishing in detail the numbered routes, that the state commissioner of highways may change or divert the present location of the roads or routes of the state highway system whenever it shall appear to him that "any part or portion of a state highway as now defined and described" shall be "dangerous or inconvenient," excessively or unreasonably expensive in construction and repair, "either by reason of grades, dangerous turns or other local conditions." This was certainly a step forward, even though official legal construction of the act itself has resulted, practically, in limiting the relocations found desirable to stretches of the existing highway between points mentioned in the act locating the highway in question.

Most of the problems connected with road improvement have been begun at the road surface. It has taken time and a general awakening of interest in the art to uncover the fundamentals and to expose them for examination and comprehension in order to solve properly these problems for satisfactory superficial results. And it has required them and the development of the automobile to expose the problem of highway location in all its importance, to direct public interest toward the problem, and to set scientists and economists to work at comprehending it and establishing theories and formulae for its solution.

In relatively recent years the public has acquired some comprehension of city planning and some progress has been made in the science of it. Most cities have, like Topsy, "just growed," though one at least—our own national capital—has developed along a well defined and preconceived plan. But

all progressive cities have been brought to considering possibilities for correcting, through proper planning, their defective lay-outs even at this late date, and wherever new cities or villages seem conceived to be born now-a-days, plans for their development are prepared in advance. Similarly regional planning for areas around or adjacent to cities is attracting attention and being studied. One incentive in this latter matter is undoubtedly the automobile with its increased radius of action for the transportation of both persons and goods. With the further development and improvement of the automobile, which is sure to come, shall not this regional planning be extended to far greater areas or, at least, to embrace in the near future the connection of skillfully planned regions by suitably located highways?

It is hardly to be expected that the old roads will entirely disappear in any event. It would be absurd for any man or any group of men now to attempt to impose on the map of Pennsylvania, for instance, a system of state highways, aggregating ten or even twenty thousand miles in length, disregarding the existing roads and considering only the connection of the larger centres of activity and the topography of the country as the controls of the lines. Even should an apparently reasonable system be thus proposed no one could say with confidence that such a system would continue to be satisfactory by the time it could be built.

On the other hand, every one knows from his own experience in traveling over the public roads that absurdities of location are constantly to be met. They vary from a little detour forced on the local traveler, by the ramp leading up into a farmer's barn placed too near the road and thereby obstructing to a greater or less extent public use of the road purely for the convenience of the individual, to the detour forced on the traveler over longer distances who has to go two or three miles further than should be necessary because the public highway improved between two large termini swings off to one side for the benefit of some small village

or settlement, which latter contributes very little to the traffic on the through road. Or it may be that the truck carrying produce to market from a considerable distance has to consume excessive time and fuel in following the old road on bad locations with unnecessary grades that now are of no advantage to any one.

Frequently, when the subject of highway location is brought up, it is dismissed by a reference to "Wellington." Such a disposition of the matter seems unfortunate and to indicate, possibly, either an unfamiliarity with the Wellington text or a lack of real comprehension of highway location problems.

The science and art of steam railroad location were exhaustively set forth in that monumental and wholly admirable work, A. M. Wellington's "Economic Theory of Railway Location," many years ago. They have received the benefit of wide discussion and investigation since, with the progress naturally to be expected. The railway conclusions cannot be applied to highway problems, except in a most general way, because of the great differences in the character of the motive power and vehicles, if for no other reasons. However, the problems of highway location are being recognized and, here and there, analyzed at last.

If one interested in locating roadways for modern highway traffic will carefully read Wellington through, he will undoubtedly be impressed with the magnitude of his work; the admirable discussion in detail of railway location; and the infrequency with which anything but the most general principles can be found that can be applied to highway location problems of today. From the viewpoint of the highway engineer, the "haystack" holds, but hides, a very few "needles."

In a way the problems of railway location compare with those of highway location as do plane and solid geometry or astronomy. Perhaps the "geometry" of highway location is "fluid geometry" rather than any one of those mentioned.

Considering the circumstances, anything else could not have been expected. A vast new continent, undeveloped, even unsettled, whose only inhabitants were wild animals and men lacking wheeled transportation, was gradually being opened up and settled by emigrants from an older civilization. These came as individuals or small groups and the individual interest was prominent if not preponderant.

Any conclusions that had been reached by the more highly civilized and developed Old World countries, or any examples that had been set there for highway work—especially highway location—could then, it is evident, be only dreamed of at best among the early settlements in this country and set aside so as not to interfere with the more important needs for meeting the demands of the times.

"The road-making of the colonial era was necessarily limited in extent and strongly marked by local characteristics. There was no powerful and sympathetic central authority to map out great through routes, and provide ways and means for constructing them, and it was only under such or similar conditions that the Romans had built the superior highways which gave rise to the saying that all roads lead to Rome. So far as the British government could influence the subject while the colonial system existed, it preferred to perpetuate commercial disseveration, so that all trade might be monopolized by its own merchants and manufacturers, as far as possible, and a cordial union of the people of the thirteen colonies be prevented."*

Following the welding of the local settlements and interests into a new nation, and the perception, here and there, at least, of its entity, came some recognition of the needs for highways other than waterways. Most of the demands were purely individually or collectively selfish. A settler out of the village desired a road opened for his benefit toward a neighbor or the village. A village desired a road to a larger centre or to a port. Centres and ports wished highway connection with the capitals with which they had to do business.

The provision of roads to meet these demands was difficult for the new community and its parts. Frugality was

*From "Development of Transportation Systems in the United States," by J. L. Ringwalt, editor of the *Railway World*, published in Philadelphia, 1888. Page 24, "Defective American Roads."

vital and whatever principles were then known to underlie highway location had often to be ignored for the sake of economy in first costs. A highway between two centres had to be wound around perhaps among the farms of several individuals in order to satisfy to some extent the needs of all with a minimum of first cost for results. A roadway meandered along the common boundary of two or more farms in order to avoid damages to one of the individual owners. As yet the evidence of community interest in the location was faint—and even in cases of highways between centres of population the actual recognition of the public interest in directness, ease of passage and ultimate economy through proper location was submerged usually by the more clamorous and active concern for the avoidance of damage or the creation of benefit to the individual.

When the construction of roads between villages came to be undertaken by the turnpike companies as commercial propositions, regard for the public interest was at least reflected in their usual directness of line, even if a certain disregard seems to have been held—probably for want of better understanding—of the ill-effects of excessive grades. When the national government authorized the construction of the first interstate road, the maximum grade was, as before stated, limited to five degrees from the horizontal.

Evidently about this time the conception of the priority of public interest awoke, if only to relax and sleep again during the period of railroad development and until the recent revival of public interest in highway improvement.

The first highway location problems in the United States were individualistic, socially, politically and economically. Where a public road was justified, i. e., between what geographical points or what of the average routes should be chosen for improvement, was a primary problem in whose proper solution, notwithstanding its now recognized importance, engineering advice seems most frequently to have been conspicuous by its absence. The problems then left to the

Fig. 2. "Tempora mutantur."

engineers were those of materials and methods of work, of frugality, and of inventions or discoveries on narrow professional lines.

After most of the public roads of this country had existed and become well established in their locations, came public demand and support for the betterment of their surfaces. Then the engineers, carrying the responsibilities for producing the particular results desired, began to demonstrate that, coincidentally, other benefits could readily be secured and, indeed, should be reached for, such as, for instance, grade reduction (by cutting and filling before surfacing) and shortening of distance or other line improvements within or immediately adjacent to the existing right-of-way in any case.

It may be said that, almost contemporaneously, the engineering profession began to generate a progeny now named the "highway engineer" who, in his growth and development, has, it is believed, helped the profession to demonstrate its

Fig. 3. Old-fashioned road location.

ability and value as an active capable factor in the solution, for the benefit of the public, of the broader problems of social welfare, economics, and even of policy—referred to heretofore as previously self-arrogated to others many times no more competent.

Another gigantic factor that has developed in the past thirty years to affect tremendously now all problems of highway engineering and to emphasize the prominence, among these problems of proper location, is the automobile.

The best available figures* show that there were, in 1903, 0.238 draft animals per capita in the continental United States and territories and but (28755)† .000355 automobiles per

*U. S. Dept. of Agriculture.
†N. M. Isabella "Roads and Streets," Feby., 1924, p. 204.

capita. The then controlling traffic factor in road problems is apparent, especially as experience then with automobiles was insufficient to suggest even rational vision for future expectations.

Twenty years later the horses and mules on farms are estimated at 0.218** per capita and the automobiles at 0.143‡ per capita. The change in the character of highway-use, in one respect at least, is apparent from these figures. At least its size, and form changes are evident. And we must admit another important character-change not shown by these figures alone. The speed of traffic has greatly increased.

The points especially desired to be made by the writer of this foregoing resumé are: the wonderful changes (from relatively simple conditions) that have developed within a human generation; the complicated nature of present highway problems in which the relative importance of location can be observed; and their possible future intricacy, from developments in highway traffic, already suggested by present conditions as probable, within the life of the improvements now being made in the public road systems and well within the life of many of the bonds being issued to pay for these improvements.

**U. S. Bureau of the Census.
‡Highway Magazine, May, 1924, p. 2.

CHAPTER III

PRESENT SITUATION

"In uplifting, get underneath." —*George Ade.*

THE importance of proper highway location seems now to be attaining fairly general professional recognition and at least to be visualized by the traveling public. This importance can hardly be over-estimated. A relatively little consideration of such items as permanency of location (as compared with the transitory nature of the road surfacing, for instance); of safety or danger to travel by good or bad location; of economy in construction, maintenance, and operation costs; of enjoyment of the highway; of its effect on the development and prosperity of the regions it serves, as well as on the abutting properties; and many other appreciable results that must be recognized as accessory to the location itself will enable anyone to estimate the supremity of good location among the other features of highway work.

A decade ago the author tried to emphasize this in one of his sections (Preliminary Investigations) of the "American Highway Engineer's Handbook." Probably further argument on the point is now unnecessary here, though the writer invites consideration of the fact that the relative importance of location has been greatly increased by the developments of recent years.

The *surface improvement* of existing roads was the first (and perhaps until recently the main) object contemplated and provided for by appropriations of public monies for that purpose at the beginning of the current movement about thirty years ago. The sums so provided seem now relatively meagre, but they were then considered generous at least. As

progress was made within limited spheres of action, the conceptions broadened, the limitations were extended, and the provisions were increased. Now there are one or more situations whose scope is so broad as to make the thoughtful pause, a moment at least, for a survey, or at any rate a reconnaissance of the destination to be sought and the path to be taken.

What is the intent of the provisions by a rich state of a bond-issue of fifty million dollars for the "*improvement* of a system of highways connecting the important county seats or centers of population" in that state? And in the work, how far is there justification for disregarding the established circuitous routes of the older connecting roads; for relocating, according to scientific methods, regardless of property developments between centres, the crooked and indirect old game-trails that have grown into roads; and for anticipating, on the basis of the experience in the past twenty years, further traffic developments in the next twenty (or the life of the bond issues), and for attempting to pursue consistently a course of action from now on that will probably produce results which will be satisfactory to the traffic needs for at least the period of the life of the results and of the bonds?

One other (perhaps subsidiary) question to indicate in a general way the nature of the field about to be passed through, and before beginning to pick our way along: What are the developments of traffic and in its demands, to be expected in the next twenty years, and perhaps to be deduced from past experience? Specifically (to illustrate): It may be conceded that there must be limits to weights of loads and vehicles—for otherwise bridge design could not be rational—and that parallel routes can be provided for extra-numerous vehicles. But must we concede that the average speed of traffic is to continue to increase indefinitely on the ascending curve furnished by the data from the past ten years, and is it obligatory to plan curves in highway location accordingly?

When modern road-surface improvement began in this country a generation ago to satisfy the demands for "hard

Fig. 4. A minor relocation in the interests of faster traffic.

surfaced roads passable the year round," two lanes of normal traffic occupied hardly more than twelve, or at most fourteen, feet of width, and a public right of way for the roadway, with its ditches, seemed sufficient at 30 feet, except possibly for the slopes of deep cuts and fills. And where cleared farm land of good quality soil would be otherwise invaded by the slopes, the cut or fill was sacrificed by simply leaving the grading undone, or, by avoiding the necessity for it, by turns and detours. Most farms kept such a supply of draft animals for field work as was ample to overcome the deficiencies of grade in hauling over the roads, and the low average speed of road traffic (perhaps five miles per hour) relieved the sharp turns of the road, in most cases, from a generally appreciated element of danger or objectionableness, except in those instances where the individual selfishness of a property owner responsible for the turn was too transparent to the public.

Not until the road surface had been improved to permit all the year travel and a higher average speed over it did the deficiencies in the location begin to be generally appre-

ciated. Even then only those defects "away from home" seemed really to be more important than the value of the land or the change in the shape of a field required by a better location. And not really until "Lizzie" or "Henry" had become the "middle name" in the American farmer's family and the desirability of an average traffic speed between five and ten times as high as previously become usual has there come about a general agreement to the propriety of avoiding unnecessary turns and of reasonable curves when needed at whatever cost (including, if proper, compensation for damages to private owners) for public highways.

With the establishment of the propriety of providing for speedier traffic came, incidentally, the recognition of the need for wider traffic lanes; in some cases, at least, of more numerous lanes, which involved, of course, greater total widths of location or right-of-way; of easier (flatter) turns, and for grades that would not reduce speeds too much and that would at the same time permit heavier loads to be hauled with the power available. The public soon appreciated the advantages, many times to be offered by relocation, for the purposes of improving turns and grades, and for relieving the traffic limitations imposed by both. They appreciated the relief of simply widening considerably the old locations or rights-of-way. And, contemporaneously, the more or less narrow and circuitous routes that had become established as highways between original important centres of population began to receive public criticism as to their excessive length, indirectness, and insufficiency on the same basis as the "close-ups" of the more local corners.

Modern road improvement, from an originally educational movement as until then directed, began to be accepted as a business proposition on the part of the state. The limitations of the activity of a state in the business have become more or less recognized and as a result the scheme of a state highway system of main roads, which should be made accessible and useful to all the citizens of the state by county or town-

ship-built feeders to it, has been widely adopted. Consequently, that it now is the duty of the state to locate or even to relocate its main roads to the best possible advantage will not be disputed.

The selection of the routes for a state highway system has almost always been done by large representative bodies, and after much open consideration. But in the indentification of the routes, innumerable opportunities for variations in the location are frequently left open by chance or by design. In some cases the responsibility is placed on the highway executive for the proper location of the routes between controlling points or even for the whole route, as for instance, under the Pennsylvania highway law. And, with this freedom of action expressly allowed the highway commission, probably comes sequentially and inescapably the *duty* to exercise a discretion in matters of location. The question, therefore, as to the scope of consideration, allowable or compulsory, arises.

It is one thing if a selection of existing roads, with minor improvements in their lines, confines the action. But then one will need to decide when improvements in lines pass beyond the "minor" stage. On the other hand, the greater power and endurance of the present motive-power of highway traffic now-a-days permits much higher grades than formerly agreed upon or generally accepted as the maxima for main roads. And the steeper grades permissible will, in many cases, encourage the entire abandonment of an old road, weaving its way around the hills to avoid excessive grades, for the sake of a shorter and more direct and economical line over them. The developments and culture may be—generally are, in fact—along the old road. But, one may note, the laws usually refer to the "improvement" of the "public roads."

It seems questionable how far the opening of new roads, the abandonment of the old ones, and the consideration of through traffic, as against the accommodation of local travel, may be carried in view of and with proper consideration of

the public—or sociological as against the commercial—nature of the enterprise and the bases of the support of it.

It is frequently the case that the location of an existing main public road between two adjacent county seats (or two important centres) could be considerably straightened, shortened, and made more safe and more economical in construction, maintenance, and operation under modern traffic by a new location that would cut loose from the development intermediate between the extremities of the route and permit advantageous recognition of the modern improvements in vehicular traffic for speed, flexibility and power.

Applying the idea to the state or national highway system, one can readily see the possibilities for considering new arrangement of routes, largely newly-located, for the economical service of through traffic.

But do traffic needs as a whole justify the involved disregard for purely local traffic or will such be the case within the next twenty years? The actual facts on which to base a reasonable forecast are meagre, and, to the writer, do not seem to justify extreme views in the matter.

A study of some recent "transport surveys" made in California, Connecticut, Maryland and Pennsylvania reveal apparently certain facts, among which may here be cited the following:

Through traffic, even with the enormous increase by the automobile developments of the past twenty years in the "radius of action," is still much in the minority except on a few trans-continental routes across states like Arizona or New Mexico.

In Connecticut, two-thirds of the business by motor is hauled less than thirty miles. Two-thirds or more of the passenger traffic is non-business and is within a radius of thirty miles. Eighty-nine per cent of the total truck traffic was of Connecticut trucks transporting over 86% of the total tonnage, and more than 81% of the commodities carried originated within the state.

In California the average from five observing stations, located on the main routes near the state line, showed that in 1922, 33.7% of the passing cars bore other than California license plates, while the percentage of foreign license plates to the whole count in the state that year is reported as less than 15 (in the average).

In six national parks the travel records similarly showed, for 1923, that 35% of the entering cars were from outside the state in which the park was located.

In Pennsylvania apparently the analyses of the traffic on the state highways are analagous to those of Connecticut. The far greater part of the traffic is local (tributary within thirty miles to the centres), and trans-state travel, even on the well advertised routes, is relatively a small fraction (less than 10%) of all the travel thereon. That old prolonged cry of "Build roads that go somewhere" even yet seems hardly to have justified some of the demands for inter-state or trans-state roads. And one may seriously question the propriety, even with the utmost consideration given to the development of traffic—nationally to be anticipated—during the next twenty years, of now endeavoring to locate a new gridiron or net work of state highways disregarding the existing roads that furnish local service. The foreign licenses noted in Pennsylvania in 1923 were 15% of the total count.

On the other hand, the present small minority indicated may be or become of importance disproportionate to its actual numbers. A state or national system of roads cannot exist as such unless it is completely linked up, even though the connecting links seem relatively useless for the moment. Again the need of the link is by no means measured by the use of or the strain put on it in numbers or weight. Neglecting the link or connection might paralyze the whole or an important part or member of the system.

It seems probable that the use of the links in the state systems between the more heavily traveled networks around the centres of population is steadily increasing. Maryland,

for instance, reports an increase there of foreign traffic to 35% of all the traffic in 1924 from 27% in 1923.

Assuming, however, that minor relocations of existing routes are not only justified but demanded, some questions arise of primary importance. For instance, the old saying that "the bail of a bucket is no longer when lying down than when standing up," used so often heretofore toward the end of avoiding grades, is true enough as stated, but length may not be the only criterion by which to determine the solution.

Within certain limits of length, grades between the level and a rising one, up to a definite maximum related to the surface condition of the roadway, can be considered as not reducing the motive power's efficiency either in the case of animal-drawn traffic or in the case of motorized traffic. A considerable increase of the allowable maxima for the rising grades may be made for the latter, but it is as yet unsettled just what the greatest allowable rising grades may be for any motor traffic before this efficient operation of the motors is affected.

Hence, it seems impossible now to answer such important questions as are naturally suggested by the above, such as:

In what inclined angle will the plane of the "bail" be most efficient for traffic now or in the future; and

What distortion (in its normal plane when canted) of a circular "bail" may be permitted without loss of efficiency in traffic, considering the direction of the mass of the latter?

The answers of the foregoing questions will seriously affect the scientific solution of a location problem.

At present about 90% of the vehicles using the main highways of the more thickly populated states, or those states where modern highway work is most advanced, are passenger automobiles. And it is well known that grades, well up to the old maxima recognized as limiting efficient horse-drawn transportation, if they are not too long, affect the efficiency of passenger motor cars, if at all, so slightly as to be inconsiderable in that connection. It may be assumed also that the genius of automotive engineering may be depended upon to

place all commercial motor vehicles on the same basis as the present pleasure automobile within a semi-generation. Then it will be important to know what maximum grades, what lengths of the same, and what arrangements or succession of varying grades conduce toward efficient operation in one direction, or both, and what do not, in order that the locations feasible around or over hills may be properly selected to give both economy in construction and economy in operation.

It will be seen that the principles so well developed years ago for steam railways location need reconsideration in view of the tremendous changes in flexibility, at least, of the motor vehicle, and as before stated, their application in highway economics is extremely limited now.

The speed of highway traffic has now approached—if it may not be fairly said to have exceeded in the cases of the shorter or moderate distances—that of the railway both for freight and passengers. What the average speed of highway traffic may become within the next twenty years is problematical perhaps. At any rate, the present conception of the latter depends somewhat upon the point of view.

For an average (by numbers only) speed of probably five miles per hour twenty years ago, the curve has now probably reached the speed of at least twenty miles per hour. And the maximum sustained speed on highways of twenty or twenty-five miles per hour of ten or fifteen years ago is now nearer fifty miles per hour.

The speed to be provided for affects the economics of the grades to be selected and thus—indirectly, at least—the location. It directly limits the curvatures of the location, besides affecting the width and some other details of construction. A good illustration of the capitalization of traffic-speed values is furnished by the recent street improvements in the city of Chicago, details of which were presented in a paper before the American Society of Civil Engineers January 17th, 1924. (See proceedings American Society of Civil Engineers, May, 1924). (See also Chap. V, "Speeds and Safety.")

In the matter of curves, speed reaches an overwhelming control. All automobiles can turn within a fifty-foot radius, but of course the adoption of that minmum for curve radii would be utterly unsafe. At the first International Road Congress (Paris, 1908) the conclusion of the representatives from many different countries was to the effect that no curve on a public highway should have a radius of less than fifty metres (163 feet), i. e., not be sharper than about 34½ degrees. But with the increase since in average speed of highway traffic* this figure may now seem, or prove in the near future, to be extreme, even though the accompanying provision for minimum clear vision along the curve be met.

Possibly it will be appropriate here, once for all, for the writer to state his opinion as to further increases in speeds of highway traffic. He recognizes the speed increases that have occurred but does not believe they will continue to increase proportionally. He believes that the next decade will show some increase of average speed on the public highways but that the maximum speed of highway vehicles will not exceed the present and will probably be somewhat reduced, in fact. He believes that speed-maniacs will take themselves off the public roads (into the air probably) and that a more universal recognition of the public's rights (for pedestrians, animals and even for motorists driving for scenery and pleasure) will prevail and be observed or be enforced against certain tendencies now noticeable toward turning the public highways into speedways for a limited few at the expense of the large majority.

On such bases, it would seem as though a convention for a minimum curve radius for ordinary cases might be safely reached around 200 feet (or, say, a 25° curve) and certainly within 285 feet (a 20° curve). It must not be overlooked, in this connection, that a widespread limiting of speed to twenty or even fifteen miles per hour exists in villages or built-up districts at frequent intervals along the routes in many states,

*See "American Highway Engineers' Handbook," "Section 4," p. 180.

so that it may reasonably be expected of hurrying motorists that they will equally regard any necessarily abrupt road curves in outside locations, which, properly posted, require a diminution of speed for the moment. Those who may argue for such lines of the roadway as will necessitate no reduction of speed outside of built-up sections may be reminded that limits to the loads of vehicles are necessary for any bridge design worthy of the term, and it seems no more irrational to place a limit to speeds for the purposes of a feature of location design, curves.

Subsequent chapters on "traffic," "speeds," "alignment" and "grades" discuss more specifically those subjects above mentioned.

If, as suggested, the earlier solutions of the problems of highway location have been uneconomic, certain tendencies in the present day consideration and solution of similar problems may be regarded as swings to the other extreme and perhaps too materialistic.

It does not as yet by any means seem properly proved that the location of the highway shall be fixed by the shortest distance or the least costs in the majority of cases. The transportation backbone of the "land of the free" is the system of railroads already built. And in the broader aspect, the highways must supplement rather than (in service at least) parallel that. This applies locally as well as nationally.

Again, the service to the public of the highways of the country has broadened to include more than the drudgeries of civilization. It is not entirely economic, not wholly materialistic, and may soon, if not now, be recognized generally to embrace even some of the spiritual attributes of life. Certainly there are already elements of convenience, of pleasure, and of recreation entering into the use of the public highways and thus affecting their location.

Lately one has frequently seen accentuated as an "axiomatic principle" that no highway should be improved "in excess of its earning capacity." This can hardly be accepted

literally because we should then be prevented from investing in an improvement not at the moment justified by the traffic, but one in which there was little doubt that the benefits in convenience, comfort to the road users, would amply justify the investment or the benefits to adjacent property by enabling its development, would support the expense. And road improvements are seldom made for commercial traffic alone. (See also Chapter X).

Again, literal adherence to the so-called axiom might often logically interfere with by-passing villages or congested centres.

Within the past year or two a change has become evident in the mind of many individuals and in the case of several groups of even municipalities—where formerly there existed a very strong desire, not to say insistent prejudice—to have the improved surfacing of the state highway route laid immediately by the door of the private residence, along the main street of the village or to the central square of the town, there is now considerable support being given by the individual and by the public to the engineer's statement that such location is often most undesirable.

The noise, dangers, and other annoyances of motor traffic, which is largely from other sources rather than of local inception, have converted many laymen to the professional ideas of locating, for the best interests of all concerned, the modern roadway at least a reasonable minimum distance from dwellings, and otherwise than along village streets where local business must be transacted or than through the hearts of the towns.

Large cities now are demanding by-passes for the through traffic of interstate or similar routes of more than local importance.

Is not the deduction inescapable that future steps imminent in location solutions are those of regarding a certain portion of the whole traffic as through; of determining the termini of this through traffic; and then, as soon as its importance

shall so warrant, of locating direct routes for that traffic between these termini, regardless of existing but less direct and therefore unsatisfactory present routes?

Such procedure seems inevitable if traffic developments for the next decade prove to be at all along the lines of those of the last. The consideration may involve regional planning, which of itself already overhangs many areas of the east, and in its solution again suggests conclusions as to future highway location similar to those above expressed.

It is probably now too early to safely jump to such conclusions and the location problems of today must still be solved mainly in the light of today's needs. The new position suggested for viewing them must be reached gradually, probably, as in all highway progress so far, somewhat uneconomically, but conservatively and safely. One might indulge rather indefinitely in speculations as to the future, but the demands of today are for results—imperfect, or temporary as they may perhaps be, but actual. And the American public has no compunction about scrapping once useful construction for better whence once an improvement is seen to be justifiable. It may be well, however, for those conducting the highway work to lead it rather than to be driven.

In an editorial, "Using Highways for Freight," the *Philadelphia Inquirer* (June 6, 1925) refers to motor-truck competition with the railroads and closes by saying:

"If all local freight is to be moved over highways, the public which pays for these highways must be taken into account. The time may be right at hand when new highways, built solely for heavy trucks, must be constructed. And distributing the cost for building such roads will be a decidedly important matter."

And so will be their locations.

CHAPTER IV

TRAFFIC ACTUALITIES AND PROBABILITIES

"Tomorrow is a satire on today, and shows its weakness." —*Young.*

NO highway work is done today without a certain regard for tomorrow, even though the critical minded assert that regard in any case is myopic, astigmatic or worse afflicted.

In such a lasting and important feature as location the imminence and persistence of, with the developments from, repeated "tomorrows" must greatly affect the final solutions of the location questions even when the solution for today shall be clear.

World's Work has recently stated that in North Carolina traffic quadrupled soon after the road improvements were made. It is a matter of general knowledge that large increases so take place. The curve of traffic increase has often been platted for a past period, but authorities are by no means in agreement as to its shape when prolongation of this curve into the future is attempted.

For many years attempts have been made to measure highway traffic. In "The American Highway Engineer's Handbook,"* pp. 162 et seq., the author went into considerable detail regarding the effects, measurement, comparisons and increases of traffic of interest from the point of view at that time. Now the point of view has changed. Relatively, certain facts still hold as strongly as ever, but the aspect of the facts, or the shapes of the connections between the facts and the effects, have been materially modified with the traffic changes.

*John Wiley & Sons, N. Y., 1919.

The marked changes that have occurred in highway traffic during the past ten years may be summed up as follows:

1. Change from animal drawn or carried travel to motor propelled vehicular traffic.

2. Changes in physical character of vehicle, particularly as to greater "dead load" (of vehicle itself); greater carrying capacity for "live load"; and replacement of metal by rubber tires.

3. Increases in widths and lengths of highway vehicles.

4. Increase in speed of traffic.

5. Increase in numbers (as well as amount) of vehicular traffic in at least two ways:

(a) Essential or business traffic.

(b) Recreational traffic.

Of the above these may be said to affect directly problems of location:

1. The greater capacity of the motor-propelled traffic for surmounting grades seems to warrant changes of standards therefor. This point is discussed under the Chapter on "Grades" herein.

3. The changes affect the radii of curves and the widths to be provided for the highway (see discussion under each).

4. The increase of speeds materially affects the principles of location and the discussion will be found under "speeds."

5. The increase in numbers affects widths principally, but when a new element is introduced, or—as perhaps more actually has been the case—developed to the extent this seems to have been, its effect goes much deeper than this single function of providing room.

Item 2 above will probably best be relegated to any consideration of standards for construction and maintenance rather than to location matters.

It therefore may be sufficient here to continue the discussion under this chapter heading on the general lines of the topic with particular regard perhaps for 1 and 4. Five is discussed in the later chapters on "Recreational Use" and on "Economics."

The modified point of view of one who now wishes to forecast the future of highway traffic as it may affect the solution of the location problems of today may be interestingly indicated by citing some traffic censuses that have, in their time, been regarded as comprehensively and accurately

measuring the traffic in the past and then examining traffic surveys now considered by prominent highway authorities as necessary to the same end and for the purpose of anticipating further developments.

A traffic record kept on the present Lincoln Highway* shows this form:

Type of Traffic	1830	1834
Broad wheel wagons	6,641	6,359
Narrow wheel wagons	495	374
Single horse wagons	761	1,243
Carriages	128	107
Two-horse wagons	318	779
Gigs	18	...
Riding horses	3,116	2,817
Draft horses	39,824	42,330
Heads of cattle	5,834	6,457
Sheep	2,180	2,852
Hogs	1,180	2,852
Carts	18	24

The French censuses were first summarized on the unit of "collars" whose value was obtained by counts of traffic made on principles that may be summarized thus:

It was considered insufficient merely to count the numbers, as all traffic is not of the same commercial value, nor has it the same influence on road wear and expenses for maintenance. Large, heavily loaded traffic has a different action on the roadway from small empty carriages. Ridden horses or livestock going to pasture or market produce different effects from those which draw vehicles. In the census of 1882, and those that have followed, recognition has been given separately to motor vehicles of different types. The official reports conclude "that in order to draw from the censuses conclusions relative to the charges which the maintenance costs reach it is necessary to attribute to each element of traffic an importance which belongs to it from the viewpoint of the destructive effect exercised on the roadway." The total numbers counted were, therefore, modified by coefficients of reduction giving "figures of circulation" in units of "collars" as a "measure of use" of the roadways.

British traffic censuses were taken up to 1910 on the cer-

Roads and Streets, September, 1924, p. 516.

tain classifications and a reduction was then made to "tonnage per yard of width per year or per mile."

In general, the foregoing samples illustrate the information then thought necessary to measure the traffic, and also indicate the viewpoint of the observer in relation to past and future developments of traffic at the time (1910).

The states of Maryland and of New York in 1909 and 1910 modified their adoptions of practice in traffic censuses to include some notes concerning the traffic to indicate a regard for speed of the traffic classifications. And in their efforts to reduce the elaborate census counts for purposes of comparison these states applied a "factor" or "relative weight" which seems to have taken into account (especially in Maryland) some regard for speeds and for perhaps other effects on the road beyond those merely from numbers and weights of motor traffic.

Within the past five years the old traffic census has been modernized to appear as the "Transport Survey." One taken in the state of California in 1920 was then regarded as up-to-date. But the "survey" taken in Connecticut in 1922 was regarded as an advance. In 1924 the Pennsylvania "survey" was regarded as a further advance on this line, and its results can probably be quoted now as the most comprehensive and latest developments in traffic measurements or estimates to illustrate the present viewpoint of the observer of highway traffic and its tendencies.

In a paper before the American Road Builders' Association at Chicago in January, 1925, Mr. Wm. H. Connell* made the following statements:

"A highway transport survey is nothing more or less than an investigation with a view to determining all the factors effecting the present and estimated further transportation requirements of a highway or a highway system. It includes:

A study of the population.

Density of population per mile.

Increase or decrease in population in the last ten years.

An economic and industrial study of the state embracing occupations of the population in the different sections of the state.

Areas of various industries, such as manufacturing, mining (bituminous and anthracite coal, stone, etc.), oil, natural gas, agriculture, dairying, lumbering, unproductive forest areas, state forest reserves, resorts, etc., indicating the major changes in the importance of these pursuits during the past several decades.

The amount of production from the various pursuits in the different sections of the state indicating the major changes in production within the past several decades.

The origin and destination and percentage of the production of the state and from without the state transported over the highways.

The quantity of the different kinds of goods transported.

An estimate of the volume of commodities resulting from the various pursuits transported over the highways and the percentage adapted to highway transportation as compared with the percentage now handled by highway transportation.

The movement and characteristics of the passenger traffic, including the origin and destination of the travel and whether business or recreational.

The present status of the public bus service and commercial trucking lines as compared with an estimate of the possibilities for expansion of these services.

"The information obtained from the traffic surveys is constantly used in connection with the location of the highways. The location of the unpaved highways is determined upon after a thorough study of the economics of each individual situation. The report on each proposed relocation embraces a statement consisting of a comparative description of the present and proposed routes, the population of towns through which they pass, a description of the character of the country, estimated cost of construction and maintenance, amount of damages for right-of-way, and the annual operating costs of the estimated future traffic of each location under consideration.

"The economics of the location of highways is of very considerable importance. The through routes particularly should be located with a view toward carrying traffic by the shortest route and over roads with reasonable grades and curvature. Most of the roads were laid out for local horse-drawn traffic without much consideration being

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*Deputy Secretary and Engineering Executive, State Department of Highways of Pennsylvania.

given to selecting the shortest route between distant points. The old highways, therefore, are not as a rule on the economic location."

Mr. Connell then gave some conclusions from the recent transport survey in Pennsylvania, from which the following extracts are taken:

"The results of the survey indicate that 92% of the traffic is local and 8% through traffic. In the summer, 85% of the traffic consists of Pennsylvania cars and 15% foreign cars. A number of the foreign cars constitute part of the local traffic in the counties bordering the adjoining states. The traffic count in these counties shows 75% Pennsylvania cars and 25% foreign cars. The traffic count of the counties in the central section of the state shows 96% Pennsylvania cars and only 4% foreign cars. The indications are that of the passenger travel, from 30% to 40% can be considered as business travel. The winter traffic is about 50% less than the summer traffic.

"Prior to the traffic studies made in Pennsylvania, both the engineers in the department and the public had a greatly exaggerated idea of the amount and weight of truck traffic. It has developed that this traffic amounts to about 10% of the total traffic and about 22% of the total tonnage on the highways. The heavy truck traffic, or loads over 18,000 pounds, amounts to about 5% of the truck traffic and only about 0.5% of the total traffic. The heaviest truck traffic, or loads over 24,000 pounds, amounts to less than 1% of the truck traffic and, therefore, less than 0.1% of the total traffic."

* * *

"In all the traffic surveys that have been made in the different states thus far, the fact has been brought out that the traffic varies in proportion to the population it serves. The most striking general illustration of this fact is the comparison of tributary population and traffic on two of our main east and west highways, the Lincoln Highway and the Roosevelt Highway.

"The Lincoln Highway crosses the southern portion of the state from Trenton, N. J., through Philadelphia and Pittsburgh to the Ohio line and is 360 miles in length. The population within an area of ten miles on either side of this highway from the New Jersey line to the Ohio line is about 4,500,000.

"The Roosevelt Highway, which enters the state at Port Jarvis, N. Y., goes through Scranton, Towanda, and thence across the northern portion of the state through Warren and on to Erie and from there to the Ohio line west of Erie, and is 443 miles in length. The population which this highway serves within an area of ten miles on either side of the highway amounts to 650,000. Of course,

there are sections of this highway near Scranton and Erie where the traffic is heavy, but on the major portion it is very light and always will be, as it serves only small centers of population.

"The population of the area through which the Lincoln Highway passes is increasing very much more than it is in the area through which the Roosevelt Highway passes, so that this difference will increase."

The following figures as to traffic are condensed from the same paper:

PENNSYLVANIA STATE HIGHWAY SYSTEM

TRAFFIC COUNTS

	Trucks	Pass. Cars	Total	Remarks
Max. Traffic Noted				Sat., Sept. 27, on Chester Pike, 2 mi. s. of Phila.
24 hour			15,864	
10 hour	610	9,614	10,224	
1 hour	66	1,278	1,344	1-2 P. M.
Min. Traffic Noted	12	143	155	Sept. 16. Rte. 221.
	3	6	9	Mar. 8. Clearfield Co., 4 mi. s. of Mahaffey.

Mr. Connell further states:

"The following traffic figures on the Lincoln Highway between Philadelphia and Pittsburgh, a distance of 363 miles, illustrate the variation in passenger and truck traffic with relation to the centers of population:

Vicinity	Population	Average daily traffic	No. of trucks	No. of loads over 21,000 lbs.
5 mi. from Phila...........	2,000,000	6,852	778	86
90 mi. from Phila., close to York..........	47,512	3,042	466	18
200 mi. from Phila., close to Bedford.......	2,330	995	94	4
68 mi. from Bedford, close to Greensburg....	15,033	2,281	200	14
Just outside Pittsburgh.....	600,000	3,204	295	23

"These traffic figures are near centers of population one hundred miles or so apart and they in turn vary greatly between these points. For example, the traffic near York, which has a population of 47,512 and is about 90 miles from Philadelphia, is 2,576 passenger cars and 466 trucks, while traffic to Coatesville (population, 14,515), 41 miles from Philadelphia, is 1,779 passenger cars and 266 trucks."

Enough has been quoted now probably to establish the relation of traffic studies to location problems. It may be pertinent, however, to say here a word more regarding the factor of foreign traffic.

On July 4, 1925, the writer, motoring down from Eagles Mere to Harrisburg, Pa., counted on the Susquehanna Trail the automobiles he met with a view to ascertaining the proportion of foreign cars. Out of several hundred counted it was found that the number of other than Pennsylvania licenses ran between 20 and 25 per cent of the total. This was on a day when it may be that Pennsylvania licensees were out in force, or at least as fully as the foreign licenses could be expected to be at the time. A few weeks later (Aug. 28, 1927) a similar count on an ordinary day (9-10 A. M.) gave 32% of foreign licenses.

On July 14, 1925, the writer's count of traffic over the Old National Pike between Hagerstown, Md., and Uniontown, Pa., showed the percentage of foreign licenses varied between 55 and 65% of all the traffic in several hundreds of cars counted on this inter-state or transcontinental route. One rather impressive fact noted was the large number of cars from far distant states, such as Florida, Massachusetts, Indiana and Wisconsin. This section of road in Pennsylvania, particularly between the Maryland line near Summerfield and Uniontown, Pa., is not regarded as an especially heavily-traveled route. The traffic censuses show an average traffic for this section to be between 1,000 and 2,000 cars per day. When, therefore, the percentage of foreign cars using it is as large as noted above, the importance of the highway nationally and as something more than a local convenience is perhaps emphasized.

It is evident that the aspect of highway traffic has greatly changed in the past 20 years. It is clear that in view of those changes further changes of weighty character should be expected and every effort made to forecast them, at least in so far as a lasting feature of highway work, such as loca-

tion, is concerned. The observer must be raised high enough to have a long view, though not so far as to be unable to recognize the details on which his deductions will necessarily be based.

The author claims no ability whatever to forecast the future in this respect. But he has watched for many years with intense interest the mutations of highway traffic and perhaps now may venture the following opinions:

1. Animal drawn traffic will soon be negligible on main highway routes outside of cities.

2. The curve of maximum weights for units of highway traffic will not rise much higher than at present and then will run flat, though if the curve shall be platted for the average of all weights it may hereafter be higher than now.

Further increase in the proportion of resilient tired traffic may be expected until practically all traffic is so equipped.

3. A slight increase in widths of vehicles may be expected shortly and then no more. Longer units of traffic may develop in the shape of trailer-trains to compensate for a restriction of maximum weight per loaded vehicle.

4. The curve for speeds will be flatter in the future, though it will likely be somewhat higher for the average of all traffic.

5. The curve of numbers will continue upward, but flattening off similarly to the population curves of Lewis and of Pearl and Reed for New York City.*

(a) The curves for business traffic will come to parallel even more closely the population curve,

(b) The curve of the recreational use of highways is rising very steeply from a relatively low level of a short time past. It will continue to rise steeply (perhaps even crossing above the business curve) and gradually flatten off under, but not much below, the curves for population and for numbers.

It may be quite true that designing highway details today for the needs of tomorrow is quite like putting an inscription on a balloon without a definite idea as to the inflation to be assured. But highway engineers cannot escape the duties and responsibilities for accomplishments and simply must do the best they can.

Up to the present generation the expansion of settlement

*Pamphlet from Com. on Plan of N. Y. and its Environs, 1923.

and of functional activity occurring in the development of this country has practically all been two dimensional (length and breadth); within this generation the use or effect of the third dimension (height) has become important. And now the fourth dimension (time or speed) at least appears on the horizon to demand consideration. If it is to be admitted as a real factor in the problem, perhaps some explanation of the writer's remarks will be suggested and some reasons be evident for such conclusions as have herein been indicated or elsewhere more fully developed and expressed by others to the effect that in the near future the accepted solutions will in clude:

Railway location below the ground surface;

Vehicular roadways on the surface; parking space in congested sections being provided by private interests.

Footways on platforms above the ground; and

Airways, above all, with their landing stages elevated as well as on the ground surface where permissible.

Much speculation has been had regarding a "saturation point" for motor-vehicle production or consumption, but the writer is neither able to visualize that point nor able even to calculate where it might be. In view of the billboard statistics, to the effect that 200 Fords are arriving with 720 "Wrigley customers" hourly, a saturation point may perhaps be calculated as by complicated differential calculus, but the writer has to confess that he cannot reach a definite answer for the problem. The assigning of a value to "*C*" in the final equation (supposing "*C*" to represent the capacity or desire of the individual to own more than one car) seems impossible.

Regarding a "saturation point" for motor ownership and use on the highways, probably the paper by Frederic Law Olmstead, et als, presented to the 5th International Road Congress at Milan, Italy, September, 1926, best expresses the facts. It states that the control lies mainly in the time available to the individual for the use of the car.

CHAPTER V

SPEEDS AND SAFETY

"All our knowledge of location (or speed) is relative, so that Time becomes practically a fourth dimension."

REFERENCE has already been made to the entrance of speed among the considerations affecting location in general (directness and shortness of routing) and in particular (curve radii, gradients, and by-passes of congested areas). But under the current heading it may be best to mention at least briefly some considerations of the relation of speed (with its "tweedledee,"—safety) to general matters of location, if not to any specific problem at the time.

The propaganda for "safety first" seems to have had quite a widespread effect, even if for a time its shameful side was indistinguishable in form or color from "too proud to fight."

"Safety first" does not seem to convey the meaning elsewhere that it has in the United States. It may be recalled that in America highway safety began on the point of the "watch your step" injunction of the New York subways and surface railways outside. That this point had as a basis the safeguarding of the financial interests of these corporations against liability for personal damage suits can hardly be denied. There followed the somewhat broader "safety first," with its personal and individual appeal, which may perhaps be a necessary avenue for bringing home to our nation at large a proper conception of the matter.

The Parisian practice of arresting the pedestrian run down by a vehicle in the streets of that city, and charging the un-

Fig. 5. Straightaway.

fortunate with "disturbing traffic" (Highway Code, Art. 55), may sufficiently exemplify the basis on which European ideas of safety on the public roads seem to rest and from which foundation the present attitude has been developed in the Old World capitals, where many highway problems are not only less new but, in some ways at least, better understood.

From a study of the reports of the 5th International Road Congress (Milan, 1926) one may be impressed by the recognition apparent in the minds of the higher road authorities of the public interest in the secure (safe) and steady (economic) flow or circulation of all traffic over the highways. The thought and effort seem to be toward the efficient utilization of the highways with the greatest possible integrity of the most rapid circulation practicable; first, by means of engineering expedients, and second, by supplementing, when necessary, general regulation. As long as consistent with these ends in view, the public is left unhampered in the choice of its means of highway use. Interference with the personal choice of transportation or other use of the high-

way by the individual is imposed only when reliance upon the individual responsibility, for his own and the general welfare, cannot longer be satisfactory to the community.

The majority of reasonable people agree that recklessness and waste may be synonymous and that economy of life and of damage to persons and property is desirable even at some price in time, money or other compensation therefor.

In allowing or providing for traffic speeds, now higher than before automobiles supplanted animal-drawn vehicles on the highways, it cannot be considered that the safety of the traffic is either directly or inversely proportional to the speed. Whether it develops to bear any such relation depends upon the propriety of the location and of the construction (or maintenance and operation) details.

The committee on highway traffic analysis of the Highway Research Board (National Research Council) has previously reported a conclusion that "It is believed that the slow moving vehicle is often the cause of congestion upon a main highway," and congestion is often responsible for accidents. The same committee has recently reported further that "On highways with four or more traffic lanes a minimum speed limit should be determined and enforced by law."

But it cannot be said that the efficiency of a roadway, i. e., the volume of traffic that it can, as a channel for the flow of traffic, carry is proportional directly to the speed of that traffic. As a matter of fact the results of certain studies show a most interesting tendency for the flow of traffic (measured in number of vehicles per hour passing a given point on the highway) to diminish when the average speed in miles per hour shall have risen above a rather low figure. Motorists driving at the higher speeds instinctively keep farther apart in the line. Safety subconsciously protrudes from the psychology and interferes with the volume of traffic flow.

This is particularly true when the roadway is wide enough only for two lanes of traffic each in opposite directions. In-

troduce a third lane for passing traffic and the flow will be automatically somewhat increased in volume, but the degree of safety will probably be considerably reduced. If a fourth traffic lane is provided, both the flow of traffic and the degree of safety will be increased.

The individual motorist inclines to object to direct or indirect restriction of his speed even if he recognizes that such increases the efficiency of the roadway, which in most cases he does not, but he equally at least chafes at congestion into which his excessive speed may run him. Many times he will have passed other cars in line at excessive speed only to slow almost to a stop to light a cigarette, so it may be a question as to how far his individual whim should affect this matter. However, it can be impersonally assumed that restriction of speed below a certain point in order to secure efficiency of the road in traffic volume will induce attempts at passing ahead by impatient drivers with a resulting decrease of safety for all the traffic where sufficient width is not contemporaneously provided for the roadway.

The writer, during two recent years, motored approximately 50,000 miles over the Pennsylvania roads. His regular traveling speed was limited to a maximum between thirty and forty miles per hour. Though no accurate counts in the matter have been practicable, the writer is convinced that he has passed, and constantly is passing by, more motors going in the same direction as himself than similarly pass him on the roads, notwithstanding his regulations for his drivers never to pass a car ahead unless it is perfectly safe to do so and necessary for the purpose of maintaining steadily the rate of progress mentioned, and never to refuse or interfere with a car from behind that desires to pass. He believes that accordingly the evidence is preponderant to the effect that the average traffic speed on the highways is less than thirty miles per hour; that this rate of speed would be ample for assumption as a factor in the design of highways where speed and safety have to be taken into account; and that

there is certainly not only no need, but it would be unwarrantedly extravagant, for the general public to base the design and construction of the public roadways with a view to reasonable safety for highway speeds over forty miles per hour.

Elsewhere the value of time has been noted as affecting decisions in certain problems of highway location. A writer (Arthur Richards) for the *Engineering-News Record* of June 2, 1925, on its page 349 argues that "traffic delay rather than traffic safety is the governing factor" to justify a $300,000 grade separation project at the Main Street crossing of two railroads in Chillicothe, Ohio. Perusal of this article does not give the reader any comparative estimates of the values of time and of safety though the cost of the project is justified on the time basis alone.

There seems to be a tendency in some quarters to regard modern public highways as solely for the use of high-speed motor vehicles, which, of course, cannot be correct either now or hereafter. Private ways may be limited to particular uses.

It is even conceivable that publicly owned and maintained roads (such as motor speedways or trucking roadways) may exist or be established and maintained from public funds (such as receipts from a gas-tax) for limited use by a selected type of ordinary vehicles for a particular purpose consistent with the welfare of the general public or a section of it.

It has been established by our highest courts that properly chartered telephone and telegraph lines and similar public utilities that replace individual travel as well as those utilities that carry travel have rights within the limits of the public rights-of-way. And certainly the humble individual who still relies on his natural anatomical structure for moving from place to place, either on business, for pleasure or for convenience, may be said to have acquired at least proscriptive rights in this matter if indeed his rights do not actually underlie all other usage of the public highways.

The principles of democracy, or those on which the repub-

lic is founded, support a control of individual liberty to the end that general benefit may result, but it hardly seems that end will ever justify the ignoring of consideration for pedestrians in general highway location. Wide as the roadway may be, further provision must be made for pedestrians outside of it but within the highway.

Absolute artificial control should be relegated to only those situations where abnormal conditions or developments seem, for the want of other solution, to justify repression of natural normal impulses and enforcement of the circumventions of personal regulation.

Such suggestions as requiring by law pedestrians to carry lanterns imply a feudalistic—Prussian—conception of class privilege for motorists if they do not reveal a lack of knowledge or consideration of cause and effect. As well as legislate that motor drivers shall at all times keep both hands on the steering wheel or against "necking" in the car.

If reasonable regard for the safety of all traffic requires the provision of extraordinary width or of long, clear vision lengthwise of the road, that provision should be made by proper location. Defective locations should not normally be accepted with the idea of providing the necessary degree of safety through artificial regulations that in principle and practice controvert natural, normal, human inheritances or endowments.

At a recent annual meeting of the engineers of the Pennsylvania Highway Department, an interesting paper on "Highway Safety, and Convenience of the Traveling Public" was presented by W. A. Van Duzer, equipment and transport engineer. From it may be quoted his summary of traffic accidents on state highways (Pennsylvania) October, 1923-October, 1924.

"Total accidents in the state reported to Department of Highways, 1641; (dry roads, 1193; wet roads, 411).

Most traffic and the majority of accidents occur on Sunday, with the least number of accidents on Tuesday.

873 accidents were on straight roads.

625 accidents were on curves, and 12% of accidents due to curves.

116 car occupants were killed and 1,400 injured.

36 pedestrians were killed and 65 pedestrians injured.

In 66 accidents, the pedestrian was traveling in the same direction as the car.

Two-thirds of cars in accidents were open models.

7½% of drivers of cars in accidents were intoxicated.

Over half the accidents were caused by reckless driving.

About one-fifth of the accidents were due to wet or icy conditions and could not be considered as entirely due to faults of location or of road construction."

Mr. Van Duzer suggested as possible remedies for traffic accidents:

"Proper elevation of curves.

Proper overhead clearance on bridges, trestles, etc.

Protection by flags in daytime and red lights and watchmen at night, on work through which public is traveling."

[AUTHOR'S NOTE: The immediately foregoing are construction details; the rest are location matters or closely connected therewith.]

"Wider roadways.

Standard warning and danger signs at the proper locations.

Reflecting or flashing lights at particularly dangerous locations.

Pavement marking at railroad grade crossings.

Cross-hatching or checkerboard marking at undergrade crossings and bridge abutments.

Visible traffic lines."

In spite of all that can be done by engineers and public authorities generally, in the nature of things some chances for accident must remain in the use of the public highways.

It must not be forgotten that location is made for night as well as for daylight use of highways. And, while "at night all cats are grey," things have a very different appearance along a road after dark than they do in the daytime. The roof of a schoolhouse, nestling in the elbow of a highway down a hill, and approximately at the level of the roadway around it, has caused several bad accidents to night motorists.

It will be well—if not necessary, in some cases at least—to consider many location questions from the viewpoint of the night traveler as well as from the better illuminated ones.

Roads cannot be made entirely accident-proof any more than can the bath tub, but, as perhaps suggested above, proper location decisions in the improvement of the roadways can do much to better their relative safety and to reduce the inevitable compensation—in the currency of danger and damage to individuals—to be required for their returns to all humanity in the form of usefulness, convenience, comfort, enjoyment, and even of greater speed or mobility.

Pennsylvania in 1924 adopted the principle of providing footwalks outside the roadway (sidewalks) on all concrete bridges thereafter to be built for state highway routes adjacent to towns or of major settlements. And the right-of-way requirements of that state have been fixed for widths ample to provide for pedestrians off the roadways.

Having recognized the principle that public highways are for all traffic, and equal freedom and safety for it all, and then having provided to the limit of their authority and power for such safety and convenience, the highway authorities can but add to these efforts such rules or regulations as will restrain the eccentricities of an individual or repress the selfishness of another to within the mass or average of all for the good of the whole. The public highways cannot be made fool-proof any more than can other features of this existence. And there really is much to be said for the doctrine of the survival of the fit.

The three primary colors—blue, red and yellow—with black and white make up our ordinary rainbow and by combination serve for the whole gamut of shades or tints. So three fundamental primaries underlie the provision of highways for the use of all traffic. They are, location, construction and maintenance. And in the location may well be observed that slogan (slightly modified) which has served so well the advocates of durable materials for construction: "Build the safety into the location."

CHAPTER VI

SIGNS

"Few motorists are superstitious enough to believe in signs."
—Abe Martin.

IRRELEVANT as the subject of signs at first may seem with regard to highway location principles, second thought will probably establish a fairly close connection between the two.

Admitting for the moment the reality of the suggested fourth dimension in connection with highway location—that is, that motion of traffic does affect location problems—and realizing that in the case of moving highway traffic the motion is more or less controlled, and at any rate directed by what may be reasonably presumed to be intelligence, in the majority of cases at least, it becomes evident that signs that affect the motion referred to are not inappropriate in connection with location details. Going a step farther, it may be admitted that location details may be affected by or even depend to a certain extent on signs and their to-be-expected effects on motion.

Unless it shall be admitted that details of the solution of location problems may be clarified by appropriate signs, it is evident that proper location for moving traffic will be almost impossible whenever topographic or other circumstantial differences require sudden changes from a normal and usual location to an abnormal, unusual or even different general form of location from that over which the traffic has just passed.

The design and construction of fool-proof public roads fortunately does not seem to be the responsibility of a state highway department, though a reasonable contemplation for

the safe and sane use of them surely must guide its conclusions. This consideration not only compels regard for the necessary clear vision or sight distance along curves, but also regard for any need of "spiralling" or otherwise easing the ends of sharp curves for, perhaps, an abnormally wider roadway at the curve; and, perhaps, for proper sign-posting where location peculiarities must affect any traffic.

The conclusions of such a representative body as the International Association of Road Congresses are worthy of serious consideration in this connection. In 1908 this body recommended that "the radii of curves in roads used by fast traffic should, wherever practicable, provide the best possible and an unobstructed view, and that where this is not possible, the curve being of too short a radius, means should be provided *whereby the approach thereto is in some way clearly indicated.*" Since that time, four similar congresses have been held (Brussels, 1910; London, 1913; Seville, 1923, and Milan, 1926) at which the same subject was discussed more or less. The original adoption, however, remains as above, now unaltered except for the addition of a recommendation for easing or spiralling the ends or approaches to the central part of the curve itself. (See also p. 66 under "Curves.")

Curves cannot be avoided even if it could be argued from any rational standpoint that such avoidances were desirable. The essential is to make them safe and convenient as practicable, with due regard for the necessities of the circumstances in every case. Inordinate speed of traffic is certainly never a circumstantial necessity in built-up sections, nor in rugged country, and it may reasonably be expected that, within such surroundings, the speed of motors will be reduced to limits within which even fairly sharp curves—when clear vision or, if necessity requires, proper signs in lieu thereof are furnished—will be negotiated successfully.

The conclusions of the congress, even allowing for the differences between foreign and American traffic conditions, do not, therefore, seem too illiberal to a properly disciplined

and considerate motorist. On the other hand, to intrude without warning at the end of a long, straight road in open, flat country an abrupt turn of even several times the minimum radius mentioned would be utterly unreasonable location if it could possibly be avoided, and should only be sanctioned when unavoidable and when unmistakable and infallible warnings of its existence are provided simultaneously for the traffic.

Every curve should have a reason for its existence and the reason should be evident. It might now be added that it should be evident before rather than only after the recognition of the curve. In other words, a motorist who is above the moron class and not addicted to crime should be furnished such evidence, in time before reaching a curve, as will lead him to expect one. The experienced driver, as he approaches hilly country, knows curves will be found in the road. The rougher the country, the more abrupt curvature he expects and subconsciously provides for. In the same way, a collection of buildings suggests to a driver the possibilities of curves and other reasons for care in driving. Conversely, curves may more rationally be located within such surroundings.

Traffic in cities is becoming accustomed to sharp turns, sudden stops, and, generally, regulation of movement under various controls where circumstances require the latter. And it is reasonable to expect traffic, even out in the country, to remain always subject to the control that is unavoidable at least where community of interest prevails, such as on the public highways. But it is equally reasonable to expect of the authorities representing and exercising the control that they should recognize the psychology involved in its functioning. They should locate the roadway whenever possible so as to relieve the necessity for enforcing artificial control, and to stimulate the observance of automatic control. There should be supplied where otherwise naturally lacking such

signs as will inspire in season automatic control to offset the defects of the location itself.

Without straying further now into the domain of highway signs, perhaps enough has been stated to indicate that locating and signing overlap to some extent, and the points in common to be noted at this time include the following:

When natural or normal warnings of curves fail, artificial and remarkable notices of the approaching change of roadway conditions must be supplied by signs sufficiently in advance to inspire and to result, before the climax is reachable, in the control of the traffic necessitated by the conditions.

Better effects will be had from impressions given to drivers through colors or shapes of signs than by words or phrases, no matter how clearly the latter may be arranged and set forth to the end that "he who runs may read." Now-a-days time is not taken to read such literature—and pictures, if crude but recognizable, make greater appeal even if it is not a fact that they are more generally and better understood and believed.

Highway signs must be graphic rather than verbal. Further, uniformity and regularity in signs are more easily secured by colors and particularly by shapes or forms, and the drivers of modern traffic will be more readily and effectively responsive, from familiarity with both the latter (if the idea shall be generally adopted as recommended by the International Road Congress and supported more or less elsewhere) than could possibly be expected from any sort of notice requiring the reading of words.

It must not be overlooked that many drivers are color-blind. It is now estimated that at least 10% of our population suffer from achromatopsia. The reinforcement of a warning sign in color by means of distinctive shape seems, therefore, important.

State egotism should not be carried to excess and to a result that nullifies the graphic principles of sign posting. Arrowheads and similar devices to impress the individuality

of a state on the passing motorist may be used as backgrounds for signs, which by their shape are to give important advice to the approaching drivers, unless such use would materially controvert the shape-design aims of these signs.

In such cases, or even where that result may only seem possible, the individuality objective of the state may need to be abandoned and the heraldic devices of shape confined to those signs—informative or historical—which are not of a warning character.

Pedestrian tourists used to, and probably still do, find informative signs of interest and value. Even the elaborate roadside maps and law digests displayed on "bill-board" structures by some states may justify their existence to some passers-by, though the writer has never studied one *in situ* nor has he seen anyone else doing so. And there has been criticism of their disfigurement of the landscape. As novelties they rouse for a moment curiosity and interest. Their lasting value may be questioned, perhaps, particularly when other principles, which their effect necessarily controverts, are brought into the consideration.

Carrying the thought just noted still further, the author suggests here, as a general conclusion, that before adding to the signs already along the highways and before discussing and fixing the rectification of the existing signs or the shape, color and details of new signs, it would be first desirable to consider as necessary the elimination of all signs along the highways not absolutely needed for traffic. The next step there would be the rectification of those remaining, i. e., the absolutely necessary ones. And the third step then would be the addition of further desirable signs of proper design and within the limit in numbers that would seem wise for establishment, in order to avoid confusion and devaluation of any or all. There seems now to be a danger of too much sign-posting with the probable end of worse results and confusion and a corresponding loss of value in them to the traffic.

For the sake of safety at danger points of forced locations, at least, commercial advertising signs should be kept entirely off the rights of way, and if some effective means can be devised for so doing, kept at least 100 feet away from the limits of the right of way so that they may not divert the attention of the driver from his continuous responsibilities in hand.

It may not be practicable to remove entirely all advertising from the field of vision of the motor-driver, if we recognize a certain amount of personal liberty for displaying on the property such notices as "For Rent" or "For Sale" or "Honey for Sale," but proper regulation of these signs, so that they would not be a source of danger nor interfere with the safety and pleasure of highway traffic, would not seem unreasonable to require.

The writer has before suggested that commercial advertising along the highways should by law be restricted to business done on the premises and that then the signs themselves should be subject to the approval of the highway authorities (as to their character, color, shape, size, location, etc.)

Such an exercise of the police power of the state would be in the interest of public welfare.

There is another school of thought which seems to consider attempts to save the "fool-motorist" from himself as useless. This school argues further that it is neither the duty of the highway authorities to attempt fool-proof construction nor is it their responsibility to try for sanity in motor operations over it (by signs and other means) beyond the point where safety to all the normal and reasonable highway traffic may require such efforts on their part to go. "Turn 'em loose" may be that slogan. The writer cannot hold with this extreme.

He believes that traffic should be warned in advance by highway signs of irremediably objectionable details of location; that such a warning or cautionary sign should be sim-

ple, plain and unmistakable, distinctive, and conspicuous to the motor driver, but they should not be so numerous as to make them worthless.

Near Visalia, California, the improved road from Three Rivers passes narrowly between some boulders on a curve and plunges down a steep grade. On the first rock face some one has painted in large letters "Prepare to meet thy God." Under analagous circumstances similar phrases are to be found conspicuously posted between Harrisburg and Philadelphia, Pennsylvania, and probably hundreds of similar instances might be cited. To the stranger the effects intended are probably to arrest the attention and to raise the query as to the application of the notice. However appropriate the coincidence of facts may be in this case, it becomes apparent that the indiscriminate use of such appeals defeats the purpose of the author, whichever it may have been. Aesop's fable of "Wolf! Wolf!" seems to apply.

The traffic-line on the pavement can rationally be regarded as a cautionary sign and the same principles apply to it. Its use has in many cases been overdone; but properly placed, limited, and maintained, it is a valuable adjunct for solving some location problems.

As location adjuncts, cautionary signs preferably now should be four to five feet above the level of the roadway and in unobstructed view of the approaching motor driver.

Informative signs should occupy such a different position that they can in no case be confused with the cautionary signs. Otherwise, they may be set anywhere and in any position that is convenient. Informative signs (distances, elevations, historical facts, etc.) should be accessible, legible and succinct. With these lies the opportunity for art in design, for local color and for advertisement, if such can be considered proper in this connection.

There is one sign that may be regarded as both cautionary or locationary and informative, and which is really of great

value to motor-traffic, particularly that portion coming from or going to another locality, i. e., the "route number."

Route numbers, enabling, by their proper display along the highway, the traveler to follow his course without losing the scenic pleasures of his trip through concentration on a map or a route book, have been familiar in France for years. They are beginning to be appreciated in this country and the progressive states are now using them. Such indications of location can and should be given prominence along the highways (such as on the poles, fences or failings) without interference with cautionary signs.

Possibly the best expressed support for route numbering is that extraordinary praise sung by a British poet-laureate for an accomplishment not English:

"Now praise the Gods of Time and Chance
    That bring a heart's desire,
And lay the joyous roads of France
    Once more beneath the tyre—
So numbered by Napoleon,
    The veriest ass can spy
How Twenty takes to Bourg-Madame
    And Ten is for Hendaye."*

*"A Song of French Roads" by Rudyard Kipling.

CHAPTER VII

ALIGNMENT

"Between two points a straight line is the most tedious distance."* —*Moszkowski.*

TANGENTS

THE connection of any two places by a road necessarily raises the primary question of the course of the connection, i. e., whether it shall be the most direct practicable or whether it shall be more or less circuitous. The decision underlies all problems of location and usually crops out early in the progress of planning for work.

While a straight line may be "the shortest distance between two points," it does not seem to follow always that it should be striven for. Equally it does not always follow that a curved line of "beauty" should be insisted upon.

The more important the places being connected and the connecting road itself, it may be generally said, the more important the directness, i. e., the straightness of the alignment for the connecting road, particularly if the length of the latter is short or at least relatively short.

On the other hand, convenience to traffic, safety, operating costs, and even speed for traffic as a whole may not result proportionally to straightness of alignment even when directness of route is being sought.

Ordinarily, with two places not far apart, the most direct route will be urged for an important road to connect them, and this demand may properly result even in a tangent of considerable length for the center line of the roadway. The straightaway lines of some sections of the old turnpikes are thus accounted for and a similar factor enters into the com-

*and most dangerous—W. W. C.

Fig. 6. Normal view from tonneau of modern touring car.

Fig. 7. Same view without interference of top or dash and windshield.

mon layout of city streets; other factors contribute to the same result.

When the termini of the road are farther apart, that fraction of traffic using only a portion of the whole road length increases. The topographical difficulties in the way of a straight line for both alignment and grades also increase and there enters a factor toward deviation from the tangents of both arising from individual or minor local interests of considerable importance.

The influences for diversion or for curvature increase rapidly with the length of the route. In the laying out, over two hundred years ago (1703), of a road from the center of Philadelphia to Lancaster, Pennsylvania, a distance of sixty miles, a straight line was attempted. It was successfully carried for the first four miles (which today is North Broad Street, Philadelphia) but beyond Cobbs Creek the straight line idea was soon sacrificed to the topographical and other influences with the result that the old road has survived and proved satisfactory to the present day because of its reasonable directness, even though its straightness is not remarkable beyond the city limits. Within the city the tangent line of North Broad Street seems to have given equal satisfaction.

Again, in the case of the "Main Street of America"—the Lincoln Highway (3,143 miles), a transcontinental route of primary importance and popularity—where directness, in the sense of straightness on a larger scale, might be considered important, it will be found that the direct line from New York to San Francisco passes through Omaha as does the route. But the influence of Philadelphia and Pittsburgh, Pennsylvania, and Fort Wayne, Indiana, have detoured the actual highway location to the south by a maximum of eighty miles. Between Fort Wayne and Omaha, Cedar Rapids (Iowa) accounts for a detour from the direct line of forty miles. From Omaha to San Francisco, Cheyenne and Salt Lake City detour the location north of the direct line.

As sections of the whole transcontinental route are separately considered, similar variations from the most direct, shortest and straightest possible alignment are to be found dictated by local conditions. There are to be found, however, many short sections where long tangents in the roadway centre line do exist and seem entirely proper.

Nothing in the foregoing should be taken as criticism direct or implied on the routing of the Lincoln Highway. It is merely used as an excellent illustration of the fact that even in highway alignment "the eternal fitness of things" must be considered and that the theory of relativity actively applies.

A concomitant factor affecting the alignment, either in the selection of a through route or in the determination of the location of the centre line of the improved roadway to be, must be the actual public right-of-way of the present road where such a one is at all involved.

The growth of the existing road situation has been sketched, and the point made that many times theoretical directness must now be sacrificed for the sake of accommodating developments that have ripened before indirectness became worthy of such consideration. And, reducing the extent of the proposition without altering the principles, it will become evident that always the propriety of abandoning an existing right-of-way, merely to secure a longer tangent for the centre line, should be carefully weighed.

Commercial transportation by highway of passengers or goods from New York to San Francisco is beyond consideration. The through traffic must be classed as "pleasure travel," to which the extra length, caused by any indirectness of the Lincoln Highway as before selected in illustration, cannot be considered as objectionable. This fact may again be found to apply in numerous instances on smaller scales. In some instances, however, the opposite conclusion is reached, as will later be seen in the text under "Economic Theories and Formulae," Chap. XII.

Many who may not have considered the broader aspects of the question seem inclined to regard directness and straight lines as ever-living Gods to be sacrified to constantly. This attitude on the part of some engineers often comes from previous experience on railroads where the tangents sought for in track alignment are desirable by reason of the relative rigidity—as compared with the flexibility of the highway automobile of the motor—there used.

A straight line (or grade) often involves greater costs for construction than one more closely accommodating the topography, though it may perhaps require less expense for operation if such operation shall be commercial.

The maintenance of straight highways is more expensive than that of those properly curved or rolling. Excessively straight lines (and grades) induce speeding and increase the dangers to traffic as shown by the records of automobile accidents, two-thirds to three-quarters of which annually are recorded as occurring on straight roadways.

Considering the present and even the seemingly probable future proportions of pleasure to business use of the public highways, it is proper in highway location to regard to a considerable extent the scenic or aesthetic aspects of the problems presented.

"Seeing America from a car window" is better than not seeing it at all, but the desirable delightful intimacy suggested by glimpses had, as one speeds by at a distance, sidewise through a limited aperture frequently impels the observer to try for better results by riding the rear platform, for longer and less limited views, or by motoring with more leisurely intentions, at least, over the highways.

From the car window the ugliness of the alignment of the road-bed of the railway is hidden. From the rear platform it is suggested. From the automobile the same ugliness of "railroad lines and grades" is intruded on the view and offends, particularly if evidently that ugliness is avoidable.

The modern touring car is so built as to restrict or con-

centrate the view of the road by the occupants to directly ahead. The roll of the top down over the sides seems to compel the concentration of the passengers in the tonneau on observations through the windshield longitudinally along the road ahead, and this acts to emphasize the importance of providing agreeable alignment for the roadway.

There are one or two axioms of landscape engineering that could be remembered in highway location to advantage. Where a curve in a road or path is to exist the reason for it should be apparent (or supplied to be evident). And, where slopes to cuts or fills are necessary, they should have their steepest sections "rolled" (ogee-curved) into the adjoining natural urfaces in the event that the latter cannot conveniently be extended sufficiently. This latter may seem to be an ultra-refinement and outside the consideration of the subject of highway location, but the thought in the writer's mind is that the curving of the road to avoid disfiguring cuts and fills is suggested by the two precepts as a frequent desirability in state highway practice.

Assuming for the moment that speeds, as well as sizes, like weights, of traffic units will be limited on the public highways and that grades will be economically determined between definite maxima, then the proper radii for both vertical and horizontal curves will be calculable, the location of the necessary curves will be established by topographical features, and the inference is left that the ends of these unavoidable curves will be connected by tangents.

But is this the proper conclusion? Even neglecting Einstein, and recalling the formula that "a straight line is the shortest distance between two points," are such lines generally *summa desiderata* in highway location? "The line of "beauty" is the curve, and must "duty" prevent "beauty"?

The writer has in mind an example of an extraordinarily corrupt conception of alignment perpetrated on a nationally important highway in the West. A tangent some 6,000 feet long was built on the top of the Continental Divide for no

Fig. 8. A French straightaway on a Route Nationale.

reason—so far as the writer could discover by inquiries persisted in by him, it appeared almost to the point of broken relations—other than the desire "to have the longest tangent at the highest elevation in the world." The resulting roadway ran straight down a steep grade across a basin and up again, incurring a heavy snow drift in the basin annually, whereas the roadway might have run with open slight curvature around the edge of the basin on a level grade, kept above the snow drift, had better views, been cheaper to construct and would not have been 100 yards longer.

Since the beginning of road improvement in this country, with its earlier demands for purely utilitarian results, there has been a quite general regard for appearances of highway structures. There has more or less recently developed an extension of this regard to the roadsides. Occasional instances may be cited of a most commendable and farsighted regard

for artistry in highway location, but they seem to have been regrettably few in the past. In the last ten years these latter examples have considerably multiplied and it would seem now that it was time to bring in as a constant factor in all highway location a proper regard for the aesthetics of it.

It is true that the picturesqueness of the long straightaway stretches of French and Belgian roads, for instance, with their tree borders frequently strikes the visitor as charming. A more critical eye will perhaps recognize the factor that compelled many of them and regret eventually the monotony or ugliness in some cases—compared with the fascination of the curves of Switzerland. The tangents of many of our old turnpikes may inspire even more criticism to the eye that comprehends the opportunities frequently offered by the topography for better results, or that regrets the lack of tree borders to soften the lines, and which borders are with us more difficult to secure and to protect.

The radius of traffic on the highways seems to be steadily lengthening. At first purely local, an appreciable fraction of highway traffic is already interstate—increasingly so as shown by the statistics—and fast becoming national, not to say continental, "with eyes to see." Unquestionably the proportion of "seeing" traffic will be increased by regard for and cultivation of attractiveness in appearances of the highways, including the detail of their alignment.

CURVES

With the general course of a highway fixed by its direction and controlled by separated but definite points along its route, the matter of curves between the practicable tangents so as to connect properly the separate tangents with each other and thus provide a continuous channel, along which may flow easily, safely, and efficiently the wheeled traffic over the route, has to be considered.

In the arrangement of these notes it seems most appropriate to segregate the discussion on vertical curves (in the

profile or grades of the road) and place that with the remarks on grades. Here, under alignment, the remarks will, as far as practicable, be confined to those concerning lateral curvature.

One control underlying curves has already been mentioned, i. e., a reason for existence. Ample reason is usually available in the topography and it only remains to see that the cause and the effect bear an apparently reasonable relation to each other.

Another specific control lies in the regard for a proper flow of traffic—including the safety of traffic—around the curve.

If highway traffic along a roadway is compared, as it may properly be, to water or streams flowing in channels, various close analogies are promptly apparent.

The efficiency of any channel for carrying water is affected by the smoothness of its wetted perimeter just as is the highway by its surfacing. The discharge of both channels depends, of course, on the grades, i. e., the speeds of flow, and there are well recognized effects on flow from the presence of bends or turns in water channels. In closed channels (pipes) formulae determine closely the reduction of discharge brought about by elbows in the line, and anyone who has had contact with the maintenance of ditches carrying water knows from experience the difficulties brought about by too abrupt turns in the line, by the entrance of other lines, by deposits of sediment, obstructions and other interferences to steady, even flow.

It must be equally recognized that traffic over highways is similarly affected. Abrupt turns in a highway check the speed of the traffic. "Skin friction" along the sides may be caused by sudden and irregular "roughness" of side lines, even though their protuberances do not actually extend into the roadway. Parking simulates the deposit of sediment, bars, or other temporary obstructions to the flow of water and in the same way affects the flow of traffic along its natural

Fig. 9. Agreeable curvature justified by obvious facts.

channel. In addition, probably always emphasizing the effects, in the case of highway traffic it must be remembered that the latter is sentient. In some ways it is more mercurial than watery. Greater inherent inertia, perhaps, is followed or offset by greater activity and mobility and deductions from the proved facts of water flow must be viewed in this light before their application to traffic channel problems.

The prime consideration of differences, however, must lie in the recognition of the demands for safety to all traffic. Water may be wasted to some extent for the sake of other considerations; travelers cannot be. They are not even as "expendable" as "Second Loo-eys."

Here it may be pertinent to recite some recent conclusions of weight in this connection. The U. S. Bureau of Public Roads has listed (*Roads and Streets,* October, 1924, page 721,) "Thirteen Dangers Highway Engineers Should Remove" as follows:

"Blind curves and road intersections; sharp curves on embankments; unprotected embankments; narrow bridges; sharp curves, vertical curves; slippery road surfaces; steep grades; narrow road surfaces; low or rough shoulders; steep crowns; sharp curves at bridge and underpass approaches; grade crossings; and unsuper-elevated curves."

It may be noted that at least half of these are matters of location and that of the whole at least one-third are matters of curves, so that the importance of the subject may be accepted.

That the factor of speed in this problem is a weighty one may have already occurred to the reader. Turns in the traffic channel which would be entirely acceptable at five miles per hour cannot be endured at twenty. On the other hand, it cannot be necessary on the public highway to insure against turns which would be unsuitable only for speeds of over sixty miles per hour.

In 1908 the International Association of Road Congresses met in Paris with 33 countries, represented by 813 official delegates, and 2,411 participants were recorded at the congress. Among the conclusions (before referred to) adopted by that meeting of world-wide highway authorities were the following:

The future road should have:

Radii for curves "as great as possible: 164 feet at least, the curves being connected with the tangents by parabolic arcs," and

"The outside of curves should be slightly raised (super-elevated) but so as not to interfere with ordinary vehicles; no obstructions to view should be allowed at the curves."

"Intersections of roads should be visible and well opened out."

"It is desirable that the sides of roads should be clearly defined as much as possible by trees."

It must be remembered that at this time the speeds con-

sidered for motor traffic on public highways varied between eight and twenty-five miles per hour.

The international association has not yet modified, in any of the subsequent congresses at Brussels (1910), London (1913), Seville (1923), the adoptions above quoted as to curves, but there is a general acquiescence in higher limits for speed of motor traffic on public roads.

Among the states more advanced in road improvement, the concensus of engineering opinion seems to favor a minimum radius for curves—as an "ideal" or "standard" for general control—of about twice that above quoted, i. e., of 300 feet rather than 164 feet. This conclusion seems reasonable in view of the relatively long stretches of road in the United States where other interferences with the flow of traffic will be rare or absent and where a speed for most of the traffic units of thirty to forty miles per hour would be generally regarded as reasonable.

In built-up sections, where such a speed would be regarded as improper, the minimum radius for unavoidable curves would, of course, be logically reducible even to such curvature as is so often necessary in cities where right angled

Fig. 10. The winding curves of the National Road eastward from Puzzley Run, near Grantsville, Md.

changes in the route at city street corners may necessitate a route curvature with a radius as low as thirty-feet, with, of course, an appropriate reduction of speed.

Outside centres of population, and in other than flat level country, a conflict frequently arises between the desires for directness of line and the actual interferences of grades steeper than agreeable to the normal ideals. The subject of grades is discussed elsewhere in these notes, but the solution of some of the grade problems by curvature of alignment may here be contemplated.

If a hill is to be surmounted by the road, the line of the latter may go straight up the hill with a resulting grade that will equal in percentage figures the height of the hill divided by the horizontal length (in 100 feet stations) of the tangent line. Ordinarily there would be a major amount of excavation incidentally necessary with such a layout.

If this line over the hill resulted in a steeper grade or greater excavation quantities than acceptable, either or both may be reduced by a diagonal ("slanting" or "quartering") alignment up the hill with curvature at the foot of the hill from the line of approach and curvature back to the line of departure on the direct route at the top of the hill.

The diagonal line up the hill will be longer than the direct one first mentioned, and consequently the rise per station will be less. But the curve at the foot of the grade may be seriously objectionable from the viewpoint of safety for descending traffic, particularly if the tangents it connects are relatively long and conducive to speed. Also, for ascending traffic, the curve at the foot of the hill may interfere with the "run for the hill" desirable to motor drivers.

Frequently, in rougher country, the establishment of long tangents on hills becomes impracticable because of the irregularity of the topography and the expense that would be involved for their construction, if not because also of the necessity for lengthening still further, by curvature, the alignment in order to reduce the gradients.

What should be carefully considered in this matter of the use of the curves to overcome obstacles of grade is the *relation* of the curves, of their shape, and of their position, to the adjacent alignment.

Primarily, it is dangerous to introduce too suddenly into the alignment of a through route, where motorists become accustomed to long tangents, abrupt curvature. Where curvature of the route is normally a matter of fact, further curvature is not nearly as objectionable, if evidently desirable, for consequent benefits.

The shape of curves—considering first that their radii will be determined by local circumstances—must ultimately

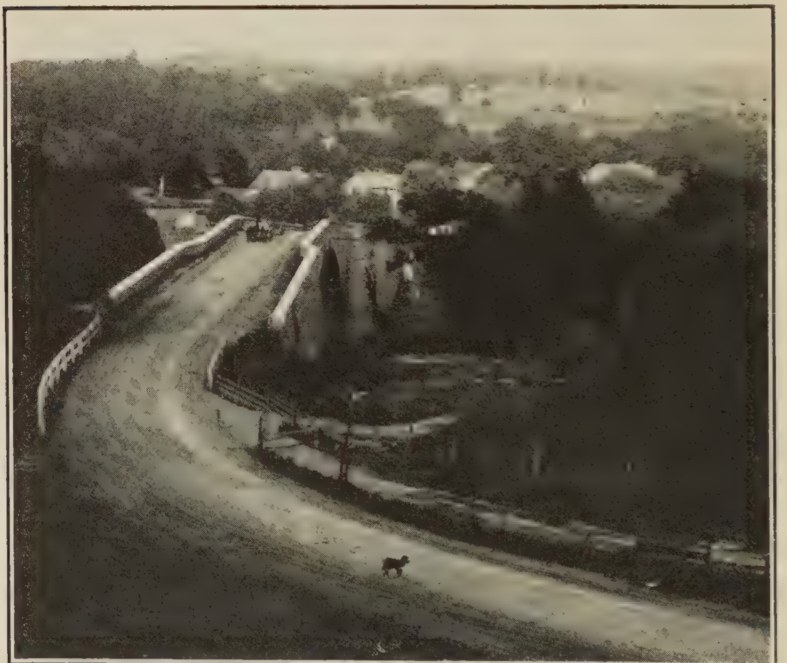


Fig. 11. The Great Old Stone Bridge on the National Road near Grantsville, Md.

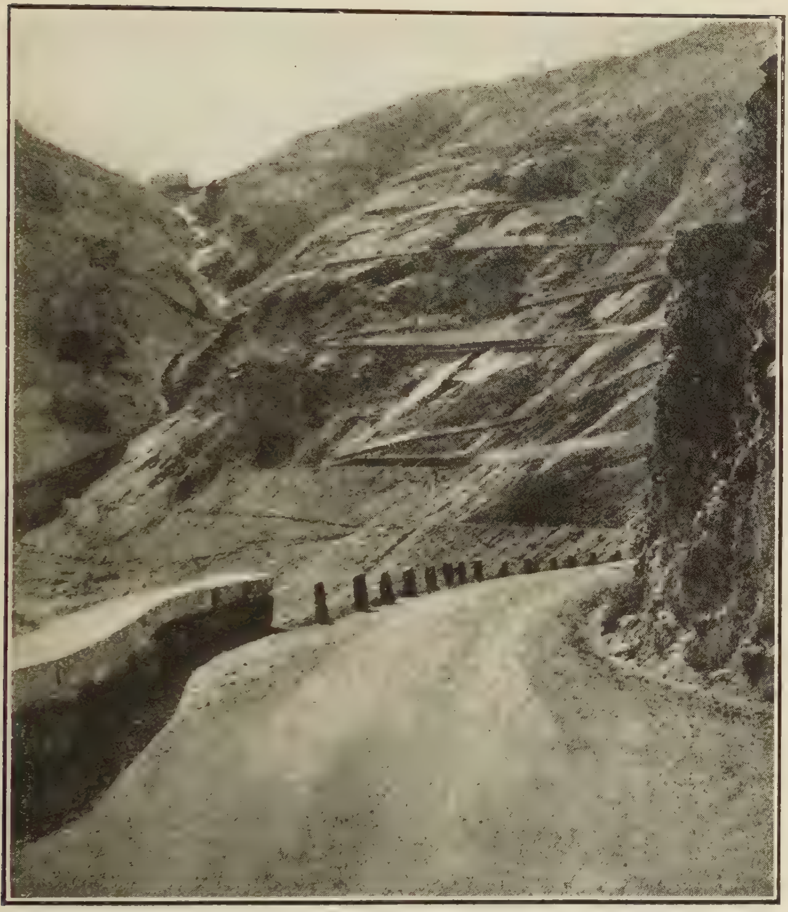


Fig. 12. The highest pass in Europe, The Stelvia, at corner of Italy, Austria and Switzerland, showing excellent road engineering 10,000 ft. above tide.

be fixed by proper consideration of the desirability for easing their ends with the adjoining alignment, especially where the abruptness of minima radii for the actual turn in direction may, under the customary speed of traffic on the section in question, make the circular curve itself relatively dangerous

either by day or night. (See also notes under the heading of "Signs").

As far as practicable, the position of curves which would be discordant with the adjacent general alignment of a route should be selected so that approaching traffic shall be given some advance notice of their presence. "Easing" a sharp curve back into the tangents does this to some extent and adds to the safety of traffic.

It may be observed that traffic moving freely from tangents to circular curves generally cuts in at the *PC's* and *PT's* and out again at the centre of the arcs. That is, the natural course of the car is parabolic, and unless the curvature is similarly placed there is danger of conflict in the traffic lanes, so that with modern speedier traffic this "easing" of curves into the tangents of the line is justified or even dictated. And when one regards appearances also, there seems little, if any, reason left for not so making the change from straight to curved alignment gradual. The effect of accurately placing a circular curve at the end of a tangent according to a carefully calculated plan, while apparently all right from above, causes the traveler approaching the curve to regard the curve as abruptly and inaccurately laid out as regards its junction with the tangent. The greater the speed of approach, the more emphatic is this effect. "Easing" or tapering the main curve back into the tangent will relieve the appearance as well as provide a smoother traffic channel.

It is true that the experienced motorist recognizes that, as the general character of the country changes from flat to hilly, the probabilities for encountering greater curvature in the alignment of the roadway increase. Also, as noted hereinbefore under "Signs," other exterior notice may be given to drivers, but perhaps even better suggestion of the need for alertness for severe curvature may be given in many cases by a progressive arrangement for the alignment so that a sharp curve is flanked by one or more less dangerous ones, or at least is not located suddenly between two long tangents

where the difficulties and dangers of the curve itself are magnified by the tangents themselves, with their encouragement to excessive speed and inattention to carefulness of driving.

A too common and most objectionable practice exists in highway construction which may be comprehended by the heading "Broken-backed Curves" and which may be defined as the location of two curves, in the same lateral departure, separated by a short tangent.*

The determination of such situations in the plans for the alignment of a roadway seems to come often from the ordinary practice of trying to fix in the field the final location of the ultimate center line, coincidentally with the running of the preliminary survey line by the field parties, without proper office correction later of the plans for construction.

It is true that if the final centre line for construction can be made to coincide with the original survey line, much equationing of the stationing is avoided; the preliminary cross sections can be used satisfactorily for estimating, and there will be less danger of errors in the office work.

Chiefs of survey parties possessing the peculiar ability to locate rapidly and well in the field are scarce. Even those best equipped in this regard generally have their perspective so limited by the conditions of highway work as to be seldom successful—certainly not generally so—in securing the best location results on the ground with a single preliminary survey. The existence of the old road, with its evident boundaries, developments, and manifest uses, obscures the keenest vision of the problems.

Examination of almost any of the construction plans put out by state highway departments whose seasonal program contemplates large mileage of results will reveal the above facts. Any motorist needs to travel but relatively short distances to note the effects in the road alignments themselves.

In railroad work (and in a few highway departments) it

*Occasionally due to topographical necessity or economy but by no means always thus excusable.

Fig. 13. "Broken back" curve. Note accentuation of ugly alignment by the well-defined edges of the roadway and the traffic line.

has been found advisable to avoid the tendencies and almost inevitable results above mentioned as objectionable by providing for location lines to be established subsequent to the preliminary surveys and a careful study of their information in the office where the plan of the alignment could be properly determined.

The "broken-backed" curves are extremely ugly to view. They normally are unnecessary and save nothing except a little effort in the office. Usually their establishment by the preliminary survey party in the field means increased expense for the survey itself because of the time lost by most of the party loafing around while the chief of party is determining the curve to be run in. They are objectionable to drivers because of the apparently unnecessary exertion or attention

demanded by the irregularity of the lines.

There are, of course, numerous instances where such location seems dictated by ledges, streams or other obstacles to better alignment, but ordinarily two lateral curves in the same departure should be separated by a tangent not less than two hundred yards in length.

With reverse curves in the alignment, it will be best to have them separated by a tangent of fifty yards or more in length in order that, at a not excessive speed, the motor driver may have reasonable time to change from the first curve to second in the opposite departure. However, if necessary, the second curve may reverse from the end of the first, if the radii are not too short, warning signs are properly supplied, and the vision for drivers not objectionably obstructed—considering the probable speeds for traffic—without serious objection from the viewpoint of appearances or of use.

Vertical curves in the profile of the roadway between grade tangents may seem to belong with the remarks on grades. They, however, may perhaps be commented upon appropriately, if briefly, at this time.

Profile tangents must, of course, be connected by curves over which vehicles may comfortably pass. Formulae have been generally accepted for determining the proper radius of curvature to this end when the gradients of the intersecting tangents are known. One such (used by the Pennsylvania State Highway Department) is as follows:

S=Safe sight distance in stations (of 100 feet) (assumed as 300 feet or 3 stations).

A=Algebraic difference of grades (in per cent).

L=Length of vertical curve in stations.

H=Height (in feet) of line of sight at ends of sight distance (assumed as 5 feet).

E=External of vertical curve$=\frac{L}{8}\times A$

Hence $L=6-\frac{40}{A}$

The minimum lengths obtained are applicable only at crests and the department recommends the use of vertical curves at either crest or hollows somewhat longer than the

METHOD OF DETERMINING LOCATION AND LENGTH OF PERMANENT TRAFFIC LINE ON HORIZONTAL AND VERTICAL CURVES.

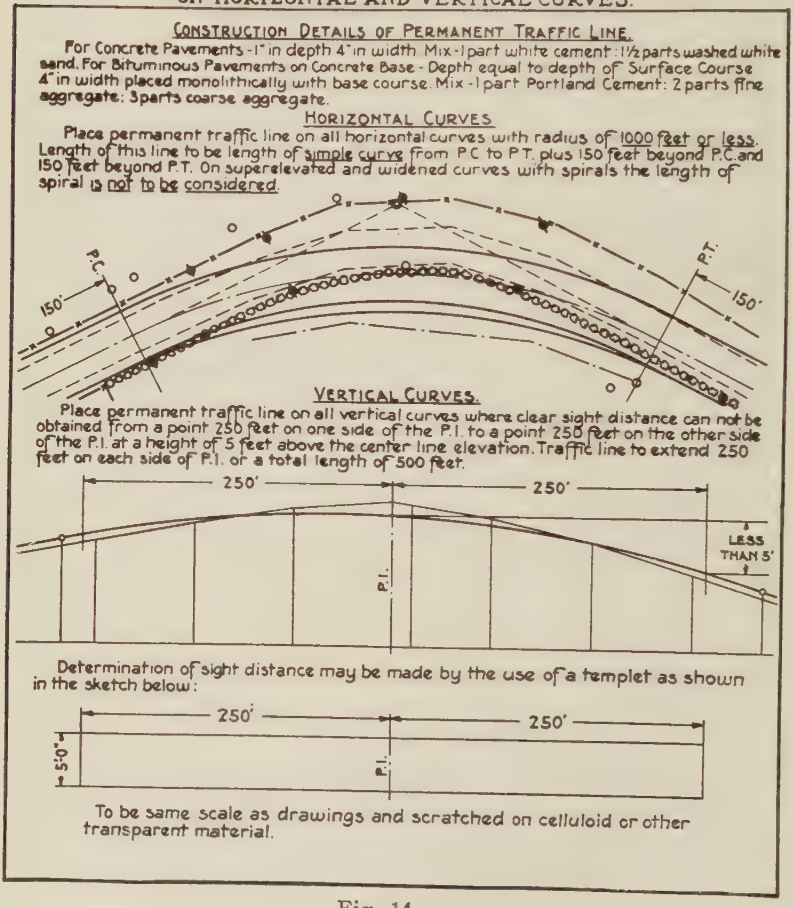


Fig. 14.

lengths obtained by the formulae. In the case of a theoretical minimum length of 100 feet, the actual length recommended by the department is 250 feet, which in the case of a minimum

length from the formulae of 350 feet the actual length recommended is 475 feet.

It will be recognized that the ability of vehicles to change direction in the vertical plane is much greater than in the horizontal even when the speed shall be included in the consideration. The construction of the chassis precludes the possibility of less than a definite horizontal radius—20 to 30 feet—while the vertical radius possible is only a fraction of these figures. The springs soften the requirements in this connection, for vertical curves, of speeds.

The appearance of vertical curves does not commonly offer the opportunity for criticism such as has been discussed in the case of horizontal curves. But there is an important point connected with vertical curve establishment which seems too often to have been overlooked.

The speed of modern traffic demands clear vision along the roadway for a considerable distance for the sake of safety. The formula quoted above intends to take this into account and it seems to in most cases. The ordinary case provided for is, as will probably occur at once to the reader, where two rising gradients intersect at a summit.

There may be another situation where the formula will prove insufficient and such cases have been noted. A long descending grade may be interrupted by a short, slight rise, so that the continuous view ahead of the driver along the road surface is broken by a blank, invisible spot just beyond the reverse curve over the rise. This is often dangerous to traffic, particularly at night when the only illumination of the roadway may be within a narrowly limited area lighted by the headlights of the car. Such arrangements of the vertical curves should be avoided particularly when a culvert or road intersection may lie in the dark area.

Consideration of visibility along roadways has been suggested by the foregoing notes on "Curves." Naturally they are complementary. Also visibility must be considered as

Fig. 15. Loop on Fall River Road west of Milner Pass, Rocky Mountain National Park, Colorado.

inseparably connected with any discussion of speeds and safety and probably with signs.

In the preparation of these notes it has seemed best to discuss matters of vision or visibility under these other headings of "Speeds" and of "Signs." Therefore, repetition will be avoided under "Curves," and only the brief statement made here that general agreement seems now to exist among highway authorities that a clear vision of at least 200 feet along the roadway shall everywhere be afforded the drivers of present motor travel.

As a conclusion to the discussion on alignment, the following axiom is offered:

What looks right may be wrong, but what looks wrong cannot be right.

Diagrammatically, the decisions to alignment may be segregated as follows for purposes of illustration:

Decision on considerations of	Decision as based on	Decision in the light of
General Location between termini Legislatively named points, or other controls	Directness—distance—curvature Spurs—by-passes of congestion Convenience Probable future developments Duplication of roadways Damage to property	Character of route Character of present and future traffic, i. e., kind and amount Width of ultimate right-of-way
Construction centre line	Lengths, grades, costs Widths—present and future Curvature and safety Intersections and crossings	Character of surfacing Numbers, weight and speed of traffic Kind of traffic Width of ultimate right-of-way
Grade crossing eliminations or separations	Embracing both "General" and "Construction" above	Needs—including considerations of safety
Maintenance work	Same as "Construction"	
Ultimate Right-of-Way Establishments	Present right-of-way Future public needs for width Protection to highway unobtainable by other means	Present knowledge of public uses of highway and tendencies toward encroachment by private interests Probable future uses of highway and interferences therewith to be anticipated

CHAPTER VIII

GRADES

"You take the high road and I'll take the low road and I'll be in Scotland afore ye."

THE song was not written with the present discussion in mind, but the quotation is nevertheless often true when applied to making time over roads in hilly country. On the other hand, the motorway which is too limited in its gradients is not apt to furnish either the quickest (shortest) or the most economical route for travel, nor is it likely to be as satisfactory to the majority of ordinary motor traffic as is one over higher points with reasonable grades and with better outlook and more apparent directness.

What maximum grades are allowable for present day motor traffic, even when the latter is segregated into various classifications, is yet an unsettled question. It must be cleared up before really scientific location is practicable, for, naturally enough, one of the first necessities for establishing a line for a highway is that of the allowable maximum grade on it.

The outstanding effort toward the development of facts for determining such a question seems to be that of the Iowa State College, which has, through T. R. Agg, C.E., highway engineer of its engineering experiment station, been since 1919 investigating the economics of highway grades based on motor-drawn rather than horse-drawn traffic. Several bulletins have been printed giving the results of the work, and Mr. Agg has in other ways contributed the facts to the public.

The publications are well worth careful study by all highway engineers. It is to be regretted that the results are not now more conclusive, but, even if they were definitely positive, they alone would still be insufficient. There would still be the need to be able to forecast better than can now be done the probable future traffic in character as well as amount.

Bulletin No. 39, February 28, 1923, of the Iowa State College of Agriculture and Mechanic Arts, entitled, "The Economics of Highway Grades," describes the tests made on grade operation and the following quotations are taken therefrom to illustrate the foregoing:

"Rules for grades:

1. The most economical rate of grade for descending traffic is that rate of grade that will permit the vehicle to descend without attaining an unsafe speed and without the use of the brake.

2. The economical maximum rate of grade for ascending traffic is that which will permit the vehicle to ascend without changing gears and at a speed that permits the motor to operate most efficiently.

3. The economical maximum rate of grade will depend upon the resistance to translation of the vehicle, the length of the grade, the allowable limits of speed and the tractive power of the vehicle.

To establish values for all of the factors that have a bearing on highway grades much information will be required that is now available only in fragmentary form.

It still remains to evaluate loss in time on excessive grades, which is a significant factor for commercial vehicles, but one that is difficult to estimate.

The value of time saved is even less readily estimated for automobiles than for commercial vehicles and no attempt is made herein to do so. It is true that a very large amount of automobile traffic is occasioned by business necessity and time is an important factor. Likewise the automobile is used extensively for pleasure."

Professor Agg's summary seems worth quoting *ad lit.* here.

"In the foregoing discussion there is presented a tentative economic theory of highway grades. The value of the deductions depends upon the sufficiency of the experimental data and the accuracy of the assumptions relative to the characteristics of the composite vehicles. There has been analyzed a great mass of data bearing on the subject and extensive field investigations have been in progress for three years, but the subject involves so many variables that the results presented herein can hardly be considered more than the first step in the establishment of an adequate theory of highway grades. Amplifications and refinements to the theory will be made by those interested as rapidly as pertinent experimental data are available.

If the principles presented herein are considered in connection with trunk-line highways, where the annual traffic may reach several mil-

Fig. 16. Cauterets—Route et chemin de fer de Pierrefille à Cauterets.

lion tons, it will be apparent that the actual value of the fuel saved by grade reduction may reach very significant sums.

The value of lost time due to excessive grades is an even larger sum, where the volume of commercial vehicle traffic is large, and undoubtedly a similar loss accrues to a considerable percentage of the automobile traffic. It is highly important to establish a basis for evaluating lost time, but it is one of those elusive quantities which are difficult to analyze.

It seems to have been established that momentum grades on rural highways are economical both from the standpoint of fuel and time and that, under certain circumstances, less fuel will be required on a road with an undulating grade line than on one with very flat grades. It is also shown that no economy results from the reduction of long grades of less than about 3 per cent and that short grades may reach 8 per cent without adversely affecting either fuel consumption or average speed.

Fuel cost is an item amounting to only 15 or 20 per cent of the cost of operation of a motor vehicle, but a saving of one-tenth of the fuel annually consumed in a state will amount to a large sum.

Almost invariably those things that lower fuel consumption also lower maintenance costs for the vehicle and thus indirectly effect a saving in repair bills and tire wear, which is considerably larger than fuel saving.

One interesting fact brought out in the fuel consumption runs was the marked saving in fuel that results from coasting down hill with the motor declutched. This is a perfectly feasible way to drive an automobile, but may be dangerous with a commercial vehicle. It should not be practiced with any kind of vehicle on long grades or where safety considerations require the vehicle to be kept under control.

Safety, aesthetics and drainage considerations in connection with grade reduction are outside the scope of this investigation, although they are factors that must always be considered in connection with highway improvement."

It will be noticed that some progress has been made with the problem. Professor Agg deserves hearty commendation for his pioneering work on this line. But it will be seen that, in spite of his efforts, much remains to be done even to plan grades properly for present-day traffic.

Many will be unable to reconcile the data obtainable from his Graph 1—where it is theoretically indicated that an 8½

per cent ascending grade should be 2,000 feet long, or that a 7 per cent grade could be indefinitely long, without objection to an automobile—and the experiences so often had in attempting such grades and coming to grief on them.

The automobile engine of today is not a high-duty engine. That is, it is neither designed for nor is it capable of heavy work for more than a limited period of time. Hence, while there is considerable "reserve power" in the engine, it gives trouble by overheating on severe grades too long continued.

As above suggested, the problems of tomorrow are not in this case certainly defined by those of today. Just what improvements in the motive power for highway traffic the genius of the automotive engineers will bring forth, in even the next five years, it is unsafe to forecast. To envisage accurately the highway traffic of ten or fifteen years from now requires better imagination and higher inspiration than seems to be available (if not also more courage) or than has been evident during the past ten or twenty years in such matters.

One writer* on highway matters has recently stated, in regard to grades, that

"Summarizing, we can say that ordinary motor traffic warrants higher rates of maximum grades than horse traffic, but demands short distance and less rise and fall on steep grades . . ."

For certain special conditions, where the trailer train must be considered, maximum grades may well be reduced below even the limits required for horse traffic.

Agg has stated in his "American Rural Highways" (p. 58):

"It is a rather settled conviction among highway engineers that on trunk line highways the maximum grade should be six per cent, unless a very large amount of grading is necessary to reach that grade."

This does not jibe with later statements in the bulletins referred to, but allowance must be made for the developments of the years between the statements by the same authority.

In view of the references by both authors quoted to es-

*W. G. Harger—"The Location, Grading and Drainage of Highways," p. 114.

tablishments of grade maxima from earlier practice, it may be of some interest to look back or a moment at those earlier standards. The grade maxima for macadam roads were developed through tests with animals by Morin, by Baker, and by others. The conclusions generally reached were that the efficient maximum for animal drawn traffic was 4 per cent. Under some conditions of topography it seemed necessary to allow as high as five or six per cent for even main roads in parts of Europe. When road improvement was taken up in this country, the best standards of Europe were recognized but reluctantly departed from in order to reduce costs and secure lengths of results. So Massachusetts and New Jersey established six and five per cent respectively for their main highways. Under similar circumstances Maryland went to 6 and even to 8 per cent in extraordinary cases, and most of the eastern states kept within that figure.

It was recognized that, for such surfacings as water bound macadam, which would invariably be adversely affected by water running down the wheel tracks or light ruts, 8 per cent was the maximum longitudinal grade which would offer any likelihood of proper maintenance of the surfacing—with the then usual "¾ inch to the foot" crown planned (and during construction reduced considerably below that in the central portion). The cross slope to shed the water to the ditches was just about equalled by the longitudinal slope of the 8 per cent grade. Hence if the grade exceeded 8 per cent there would be little hope of shedding the water falling on the roadway over such hills and every probability of damage to the surfacing there from water running down the roadway instead of to and down the ditches or gutters.

With the advent of waterproof surfacings, this consideration disappeared and the question now returns to simply that of the effects on traffic.

The changes of traffic need no rehearsal here. Some differences of opinion as to those effects have been quoted above.

The U. S. Bureau of Public Roads has expressed its

opinion that a desirable maximum for the federal aid system of this country would be 7 per cent, but the author has not yet been able to secure a clear reason for that standard.

At the Fourth International Road Congress in Seville (May, 1923) the author offered the following resolution as a basis for discussion:

"That the heretofore accepted figures for maxima grades on highways may, if desirable for economy of construction or for other good reasons, properly be doubled in cases where automobile traffic is the important one."

The program and business of the congress did not, it developed, permit the matter to be gone into there, but it is hoped that it may be taken up at an early date.

It will be clearly seen that the question is certainly a moot one at this writing, even so far as present traffic is concerned. With a view toward getting more light on the problem, the author suggested to the Pennsylvania Highway Department, in January, 1925, that certain observations of traffic be made on some hills in that state where difficulties to travel by motor over them were known to exist.

In brief, he proposed that the traffic over these three or four typical hills be observed systematically so as to determine the maximum lengths of grades of different rates, ranging from 6 to 10 per cent or over, which in practice were passed without difficulty by the ordinary motor travel of the present day.

The observations were to be complete enough to segregate the types of motors or cars; the types, at least, of the difficulties encountered; the difficulties of descent as well as of ascent, and to include notations as to weather conditions or other circumstances of possible major effect on the conclusions.

The locations suggested for the observations were on the Lincoln Highway and on the Susquehanna Trail in order that traffic from out of the immediate locality at least and not too familiar with the hills might be included.

As yet these observations have not been completed by the

Pennsylvania State Highway Department, so no report as to results can now be included here.

Within certain limits of length, grades between the level and a rising one, up to a definite maximum related to the surface condition of the roadway, can be considered as not reducing the motive power's efficiency either in the case of animal drawn traffic or in the case of motorized traffic. A considerable increase of the allowable maxima for the rising grades may be made for the latter, but it is as yet unsettled just what the greatest allowable rising grades may be for any motor traffic before this efficient operation of the motor is affected.

Hence, it seems impossible now to answer such important questions as are naturally suggested by the above, such as:

In what inclined angle will the plane of the "bail" be most efficient for traffic now or in the future; and

What distortion (in its normal plane when canted) of a circular "bail" may be permitted without loss of efficiency in traffic, considering the direction of the mass of the latter?

The answers to the foregoing questions may seriously affect a location problem, as may easily be seen.

At present about 90 per cent of the vehicles using the main highways of the more thickly populated states, or those states where modern highway work is most advanced, are passenger automobiles. And it is well known that grades, well up to the old maxima recognized as limiting efficient horse-drawn transportation, if they are not too long, affect the efficiency of passenger motor cars so slightly, if at all, as to be inconsiderable in that connection. It may be assumed also that the genius of automotive engineering may be depended upon to place all commercial motor vehicles on the same basis as the present pleasure automobile within a semi-generation.

When grade establishments shall have been made for present traffic, then comes consideration of the future. Perhaps "speculation" might be the better word.

The highway traffic of today is so changed from that of

1910 that one hesitates to detail what may exist in 1940. And yet it is upon what a number of those details then will be that rest today such determinations as that of maximum gradient now to be constructed with the promise of lasting satisfaction to up-to-date traffic.

The author has already in effect expressed his opinion that the maximum speed for which location designs should provide should not be increased. But it seems as though it might be expected that the average speed of all the traffic units might reasonably be expected to increase somewhat from the present. Further, it quite likely will be a matter of even greater importance hereafter whether or not details of location, such as grades, inflict unendurable penalties, in the currency of "time," as well as of distance, to the traffic over them.

The passenger automobile for private ownership and use seems to have reached, in its development, fairly stable types, though one can hardly say there will be no material changes in it even during the next ten years nor that such changes will not alter the effects of gradients now established for its use.

With commercial passenger cars (busses) and trucks it is rather to be expected that material changes in type and design will develop. For instance, is it not to be anticipated that at an early date the present deficiencies of trucks as to the descent of grades or as to the loss of time ascending the steeper grades may be eliminated? If the answer shall be "yes," then should not a corresponding raise of grade maxima now be justified in locating for enduring roads for the sake of ultimate economy?

Again, to what extent is it proper now to anticipate the development of "trailer" train operations for commercial purposes out over the routes away from the cities?

Bridge loads have to be limited, but the restrictions on certain lines can still be safely avoided (within some other limits) by distributing the total load in trailers. For such

Fig. 17. Agreeable curvature. Note from marks of oil droppings separation of traffic by the traffic-line around the curve.

commercial use, who can now logically forecast the gradients that will then prove the economic maxima?

The author confesses his lack of self confidence in his abilities to prophesy now in this matter. What he hopes now is that by these notes the attention of more competent seers perhaps may be called to the matter.

When future traffic seems to demand consideration in the fixing of grade maxima, by means of which to help determine location problems as before referred to, there is much opportunity for co-operative conjecture, investigation, and experiment.

In the matter of allowable grades (a control in location decisions), may not the psychological element enter?

Psychology may seem a far cry from road location, but is it so separated?

It has been noted that the modern road vehicle is absolutely responsible to the control of the human being using it; that human desires, even perhaps whims, and human ambitions, welfare, and interests affect if they do not actually determine the routes to be followed; and that human inclinations or tendencies affect the details of alignment when the consideration of safety to all is being had.

Grades requiring a shift of gears are objectionable to passenger cars, whether the shift is necessitated by either excessive steepness or length of severe rise, yet all passenger cars are provided with at least a second gear for just such emergencies.

The real reason for the objections may be entirely in the mentality of the driver, who usually dislikes the greater noise of the present "second gear" even if he is not averse to the physical effort of shifting. It may not be unreasonable to expect among the probable future improvements of the car a second gear as noiseless as the first. When that shall arrive, may it not be possible that then also there will be unavoidable regrets that in the fixed highway locations, which it had been anticipated were enduringly satisfactory, more directness had been secured at the expense, or at least without the deference, paid to an earlier phantasy?

CHAPTER IX

WIDTHS

RIGHTS-OF-WAY

"Give ample room and verge enough."—Gray.

THE approach to the problem of fixing a proper width of ultimate public right-of-way for any state highway route, which is one of a system selected from all the public roads of the state and which system is in its entirety less than, say, one-sixth of the mileage of all those public roads, is through certain existing growth and over more or less dead and fallen matter that has accompanied the development of the present situation. To reach the present definite problem will require careful clearing away of obstructions, with, at the same time, a view to providing sufficient elbow-room for working on the problem and without regrettable damage to adjacent healthy growths now thriving.

In attacking the main problem, the probabilities of the future as suggested by the past and as can, with the utmost possible effort, be deduced from the present knowledge must be kept in mind.

At first blush it may be considered that a state is (or will be) in many major respects simply an expanded city; therefore, that "city planning," "regional planning," and the like, with their accessories, can be extended or adapted to secure conclusions, such as highway widths, throughout the state system just as such widths are reached for a city's streets. Further consideration, it appears, however, will usually develop the fact that circumstances affecting the state highway widths and the ends to be obtained are quite different; that the authority of the city authorities in these matters is generally of recent origin, still more or less am-

biguous and of special and particular character, in contrast to the limited and conservative powers usually possessed by the state highway authorities for so acting as to disturb existing and well established precedents; and that generally now public opinion in no state has reached the point where a majority can be depended to support as yet an extension of the present authority over state highways to such a stage as would enable matters like widths to be disposed of similarly to the solution of such questions under a planning commission of any of the progressive cities.

Much to be desired as this further authority—properly formulated and in definite and responsible hands—may be, and urgent as it always is to strive for that, yet in this matter immediate action to the limit of the existing authority is demanded by the public interest. The conclusions necessary

Fig. 18. Damage done by an electric power company illustrating a need for the wider public right-of-way control by higher and less selfish authority.

today must be reached on the basis of present, not possible future, statutes.

In California a law has been proposed which would give the state highway authorities the power to obtain rights of way to 500 ft. in width.

The present authority of the secretary of highways of the state of Pennsylvania in the matter of widths of rights-of-way is perhaps greater than that in any other state yet delegated to a similar authority over state highways.

Under the law he is authorized (and required) to determine the necessary width of right-of-way for any state highway and to record, as provided, his determination of width when approved by the governor. Thereupon such description and plan fixes and protects the right-of-way for the public interest therein. Should private rights be infringed by such determination as above, the respective counties are required to satisfy them by the actual condemnation and acquirement of private land thereby taken for highway purposes. It is provided by the law that buildings or other improvements erected within the highway right-of-way, after the formal determination of it as above, shall not be compensated for in the final allowance of damages to the owner of the land taken. This latter point, as regards buildings, should be noted and remembered in the further discussion of this article.

Right-of-way establishment furnishes the only control that the state highway authorities have over the erection of private buildings outside of and adjacent to the side lines of the state highway. City authorities have power to fix building lines behind (away from) the actual side lines of the streets, but even in Pennsylvania the only way now for state highway authority to keep the buildings away from the actual roadway for wheeled traffic is to require a sufficient width for the public right-of-way itself.

While the laws of the state provide a minimum width of thirty and a maximum of one hundred and twenty feet, a great variety of widths for the public rights-of-way for roads

is found to exist now in Pennsylvania. There are possibly some as narrow as twenty feet, and thirty, thirty-three, forty, fifty, sixty, sixty-six, eighty, ninety, ninety-nine or one hundred foot widths are all represented.

No good reasons now exist for continuing such a variety, with its resultant confusions, and simplification is admittedly desirable. It seems practicable to select from the variety, or to establish one or more standard or typical and generally suitable for application under normal circumstances to the state highway routes, since the latter themselves are, as already recognized, selections from the whole list of public roads of the state.

By the establishment of one or two typical widths for state highway routes, it might be that more equable treatment would be generally accorded the various sections of the state. A certain desirable degree of uniformity would be given to the state road system. The relations of land owners with the public, and vice versa, would be, to some considerable extent, simplified and clarified. The routine work of local, county and state authorities would in certain respects be rendered much more simple and easy, and even less expensive.

It must be clearly understood that any proposition for a "standard" width by no means implies the rigid and unyielding application of that particular width in every single case. It merely means that the ideal width of the state highways under ordinary conditions would be the figure selected; that the surveying, planning, estimating, and discussion preliminary to the actual decision in any case would have a single definite focus from which to proceed or around which to revolve; that conflicting factors could be estimated and balanced against one another from a definite point of view or angle; that a scale or standard would thus be available by means of which any peculiarities or abnormalities of conditions might be measured or definitely estimated and expressed. On the other hand, it would equally be expected

that the selection of a "standard" width for the above reasons would show, by demonstration of its inapplicability in extraordinary cases, the need then for departures from it and suggest, rather than prevent or interfere with, other widths in such cases of peculiar conditions.

An adoption of a standard width for state highway rights-of-way would further, if properly determined, permit provision to be made now for protecting the public interest in some ways for which as yet no other means of protection is afforded, and indeed for which no generally awakened public support is yet united on particular means of protection, nor even perhaps in all cases, on all that should be protected. Those experienced in road work naturally perceive the advance on some lines before those do who are only casually interested in the roads. And the need for immediate steps in protection of the highways from encroachment is evident to most highway departments.

Therefore, the effort was first made for advance in this matter by selecting, as possible standards for ultimate widths of rights-of-way for state highways in Pennsylvania from the variety quoted, those of 60, 80 and 100 feet, with an understanding that in special cases where conditions so justified the widths might be reduced to 50 or increased to 120 feet. After much investigation and discussion, these figures were reached, as was also the conclusion that the range of these figures would permit such flexibility of application as would permit the determination of right-of-way width to approach or be analagous to the use of the roadways in different parts of the state.

The first thought, quite naturally held by many, is that the right-of-way widths are controlled by the width of the paved roadway and that the latter's width is determined by the traffic on it. That these are not the real facts can be demonstrated readily.

It is necessary that the improved roadway and the durable bridges of a state highway have at least a minimum

width regardless of the amount of traffic at any time now, and the minimum right-of-way width figures as fifty feet when consideration of proper proportions of roadway width to total width spaces for walks or trees and for poles, markers, information signs, etc., and for ditches and slopes for cuts and fills, is had along with a recognition of the fact now proved by experience that any state highway in Pennsylvania should provide a clear roadway at least 24 feet in width between ditches or guards.

Now the Pennsylvania law limits the maximum width of public highways to 120 feet. Can the intermediate widths properly be proportioned to either the existing or to-be-expected traffic on the roadway?

First taking the figures for present day traffic, of which an elaborate census has just been taken, an eighteen-foot roadway, clear for moving traffic, will accommodate safely at least 750 motors (in each direction at 20 miles per hour) per hour.*

A forty-foot clear roadway will similarly accommodate 1,500 to 2,000, while for sixty feet the number would be at least 2,500 per hour in each direction.

It is estimated that the capacity of the wider roadways would be slightly more than in direct proportion to the width because of the greater opportunity afforded for passing and for avoiding collisions. The figures given may be regarded as conservative.

The maximum amount of traffic observed in the census of 1924 on the state roads of Pennsylvania was 1,344 per hour (counting both directions) and a few less than 16,000 per day of 24 hours, while the minimum traffic recorded on any state road was nine per day.

Therefore, it would appear that the present maximum traffic over any Pennsylvania highway would be satisfied by a two-lane width of improved roadway such as is now stand-

*See *Engineering News-Record*, June 9, 1924, pp. 989, et seq. "Traffic Study Proves Two-Lane Road Widths Sufficient," by A. N. Johnson.

ard for Pennsylvania construction. However, clear width for moving traffic of 18 feet means at least 32 feet of total width of roadway for avoidance of interruption by parking, or—if we accept the most modern thought of 10 feet in width for all traffic and parking lanes—40 feet is needed between kerbs or edges of usable roadway.

Assuming 20 feet for the roadway (the latest conception of proper width for two lanes of motor traffic) and allowing 5 feet for the necessary shoulders, ditches and similar protective incidentals on each side of the roadway itself, the total roadway width would be 30 feet and the total right-of-way width indicated as at least 50 feet.

But, looking a bit afield and considering matters incidental to state highway construction and maintenance with even moderate regard for future developments, probabilities from past experience, and the important fact that it is only by means of the establishment of a suitable right-of-way width that proper protection to the highway and to the traffic over it can be insured, it will quickly be seen that this minimum width of fifty feet, even for the least conspicuous of the state highways, will seldom if ever be proper for final establishment at this opportunity.

A bit of pre-war dithyrambic verse comes to mind as perhaps illustrative in this connection:

> "Methinks there are five reasons why man drinks:
> Good wine, good friends, because he's dry,
> Because he might be bye and bye,
> Or any other reason why."

Any determination for the width of the total right-of-way for a public highway must embrace thorough consideration of the following elements entering into the matter:

1. The ultimate number of traffic (both moving and parked) lanes and width of each that will be required.
2. Widths of lanes or strips required for present or future public service easements or structures, such as tracks, pole lines, etc.
3. Pedestrian lanes for sidewalks, and reservations of width for safety islands, tree and other planting, ditches, pole lines, etc.

4. Reservations of width of right-of-way for public conveniences, comfort stations, seats, monuments, signs, etc.

5. Reservation of width for light, air, vision for safety of traffic, and for protection of public roadway in the general public interest.

The widths to be provided for the roadways should be contemplated prior to the determination of the location of any centre line.

Too often a location and right-of-way are established for a narrow road with the idea that if later the road shall need widening it will be a simple matter to proceed with that work within the original right-of-way or by extending the latter uniformly to each side. Such, in fact, is seldom the fact, and it becomes evident afterwards that economy and general satisfaction in the location would have been greater had the original location been made with a recognition of the ultimate widths necessary later and a bolder treatment of the whole problem been adopted at first.

Normally, the symmetrical development (in cross-section) of the public right-of-way is preferable. It appears most equitable to the adjoining property and the results are less likely to prove objectionable as developments ensue in the passing years.

Occasionally come cases where the centre line of the roadway now to be laid should not coincide with the centre line of the right-of-way. The latter may contemplate for its ultimate development two roadways separated by a reservation and yet only one is to be built at present. Or, but one roadway may be contemplated and yet it may be entirely proper to reserve by right-of-way acquirement considerable extra width along a water front to one side of that roadway. In both these not now infrequent situations, unsymmetrical cross-sectional development of the right-of-way may be quite correct.

In establishing a centre line for an improved roadway within, say, a thirty-foot right-of-way, it is imperative to regard carefully the often small angles and curvature of the

latter. But if now at this time a widening of the right-of-way to, say, eighty or one hundred twenty feet is possible, the opportunity offers at once for the establishment of a much better centre line. The widening may be done largely on one side, for instance, at a small angle or turn in the old location and that deflection thus removed entirely. On a larger turn the severity of the curve may similarly be eased.

Therefore, it becomes most important to know and consider the right-of-way width that will be available, as well as the roadway width to be provided, in order to fix the location properly, especially when symmetrical development of the right-of-way width is to be expected, as is the normal case.

Highway authorities are not yet agreed as to standards for providing widths of roadways with a veiw to enduring satisfaction therewith. The "single track" roadway may be regarded now as extinct so far as state highways are concerned, and the "double track" roadway may safely be considered the minimum to be located. Therefore, with the paved roadway of 18 or 20 feet, the shoulders, foot-paths, planting spaces, gutters or ditches necessarily to be considered in all cases, and, neglecting, as they may be, extraordinary slopes to the cuts and fills, there will be a minimum width of forty feet for the right-of-way to be located. But in view of proper provision for traffic increases during the life of the improvement, it will be best in most cases to regard 50 feet as this minimum wherever possible, even on country sections of state highways.

It has been forcibly argued (Dr. A. N. Johnson, *Engineering News-Record,* June 9, 1921, page 989, et seq.) that provisions for highway systems composed of roads for carrying more than two lanes of traffic (except in local short sections) are illogical and extravagant, and that paralleling roads should be provided where necessary.

Many highway authorities regard as inevitably proper the contemplation of even six lanes of traffic to be provided for by the roadway pavement. *Engineering News-Record,* May

1, 1924, editorially comments briefly on this matter and refers to a recent adoption by the highway authorities of the state of Connecticut for their heaviest traveled highway—the Boston Post Road—of 36 feet as the width of the pavement thereon, i. e., providing for at least four traffic lanes.

One highway authority visualizes a need even for providing sufficient widths to allow parking lanes on each side of several traffic lanes, thus raising the width figures even to sixty feet for the roadway and at least 100 feet for the location right-of-way.

Another prominent city planner has advocated a two hundred-foot highway between New York and Philadelphia. (See *Philadelphia Inquirer,* March 27, 1925.)

Such developments may arrive in the future, but they introduce new problems of detail, some of which are serious. Considering that the maximum traffic noted on the state highways of Pennsylvania in 1924 was 10,224 vehicles in ten hours and 15,864 vehicles in twenty-four hours on Route 130 (toward Media, Pennsylvania) at a point two miles outside of the former city, it may be questioned if these extraordinary solutions of present problems are yet to be accepted.

H. Bartholomew in *Engineering News-Record,* May 1, 1924, page 766, et seq., suggests possibilities of relief from excessive demands for width. The writer is inclined to the conviction that Johnson and Bartholomew are both right on many points and that the provision now, by suitable locations of excessively wide roadways for inordinate numbers of traffic lanes within a single right-of-way as a development from recent growths and present conditions in this matter, is unjustified.

"Traffic lines," reasonable traffic laws and decent respect by drivers for such regulations; rightful restriction of commercial "cruising for business"; proper abolition of "parking" (as distinguished from receiving and discharging passengers—not freight—with the motor continuing to run); and the placing squarely where it belongs, i. e., on

the private interest benefited, of the duty for providing, off the public right-of-way, of the parking or loading spaces needed, will enormously increase the efficiency of the public rights-of-way widths, lighten the public financial burden, and relieve or simplify the location problems involved in the provision of suitable widths.

The widths of new locations should be determined coincidentally with the alignment, and conversely the alignment of relocations, or even of line revisions, should be determined only after full consideration of the ultimate right-of-way width to be had.

Again, merely widening the present public rights-of-way for a state's highways to a minimum, or even a graded set of widths, will not meet the needs, if in fact such a proposition does not result in "confusion worse confounded."

To establish by law, let us say, "a width of 100 feet for all state highways," will result in at least two objectionable ends:

(a) The defects of the present alignment will be emphasized and, if not perpetuated, made more difficult to correct.

(b) The right-of-way widening will be unduly expensive and extravagant in property damages to be paid, particularly for damages to buildings and other "improvements" on the adjacent land.

What should be done, of course, is to authorize relocation and widening coincidentally. Then there may be some hope for improved alignment, greater widths, satisfaction with results, and economy in reaching them.

Uniformly increasing the existing right-of-way widths each side of the present centre line of the roadway may even be extremely objectionable in some cases, such as, for instance, where a roadway borders a river or closely runs along a railroad. Also such features as valuable trees, buildings, etc., along one side of the present roadway, but absent on the other, might argue forcibly against widening equally on

both sides of the present centre line. And unless relocation powers are possessed and exercised at objectionable angles in the present alignment before such uniform widening is done, little, if any, opportunity is left for the improvement of the alignment in connection with the widening. On the other hand, if the widening is skillfully done on the inner side only of some or many of the turns, they can be satisfactorily improved without further relocation of the alignment. Considerable art and judgment are required for obtaining the desirable right-of-way widths for the fullest and best results to state highway routes economically and with probably lasting satisfaction.

PENNSYLVANIA PRACTICE

"The state highway commissioner shall also have power, with the approval of the governor, to establish the width and lines of any state highway before or after the construction, reconstruction, or improvement of the same, not, however, exceeding the maximum width fixed by law for public roads. Whenever the state highway commissioner shall establish the width and lines of any such state highway, he shall cause a description and plan thereof to be made, showing the centre line of said highway and the established width thereof, and shall attach thereto his acknowledgment. Thereupon such description, plan, and acknowledgment shall be recorded in the office of the recorder of deeds of the proper county, in a separate book kept for such purpose, which shall be furnished to the recorder of deeds by the county commissioners at the expense of the county.

"No owner or occupier of lands, buildings, or improvements shall erect any building or make any improvements within the limits of any state highway the width and lines of which have been established and recorded as provided in this section, and, if any such erection or improvement shall be made, no allowances shall be had therefor by the assessment of damages." (State Highway Code of Pennsylvania.)

In view of these legal provisions controlling the right-of-way widths on the state highways of Pennsylvania, and in order to have reasonable definite and coordinated standards as guides in the departmental operations, a state-wide ar-

rangement of ultimate right-of-way widths has been tentatively mapped.

With a legislative act prescribing 120 feet as a maximum width for any public highway, the following mathematical rules were set up to govern generally over the state the ultimate right-of-way widths on the primary system of state highways. Around centers of 500,000 population or over should be used the one hundred and twenty foot width for a radius of twenty miles.

100,000 to 500,000	120 feet for ten miles
75,000 to 100,000	100 feet for twenty miles
50,000 to 75,000	100 feet for ten miles
5,000 to 50,000	100 feet for five miles
2,000 to 5,000	100 feet for three miles

The remainder of the primary system to carry an ultimate right-of-way width of eighty feet.

Such a formula proved quite satisfactory for establishing a tentative design, and the graphical results were quite readily modified in places where slight distortion of the actual results of the formula seemed to be required to bring about a fairly logical and well proportioned general ultimate right-of-way design for the entire state primary system.

The final results obtained in this way "were approved in principle" by the departmental authority, with the modifying note to the effect that, where desirable, there would be an extended use of the one hundred foot sections, and that exceptions might be made to the approved establishment in built-up localities or special cases where abnormal reasons furnished a sufficient justification. In this connection it also enunciated that nine or ten feet (preferably the latter) widths for traffic lanes should be standard and that six lanes for general use would be the maximum to be provided for by any roadway of the state highway system.

ROADWAYS

Now, in the case of streets, a definite ratio has become established generally between the portion to be devoted to

the roadway for vehicular traffic and the remaining portion (of the total width) to be reserved for foot passengers, pole lines, trees, etc., etc. This allotment is usually fixed at sixty per cent (three-fifths) of the total right-of-way for the roadway and forty per cent of the total (one-fifth on each side of the roadway) for the sidewalk reservations. Circumstances —such as the need for wider walks in a crowded retail or office building district where roadway traffic might properly be restricted, or the need for a wider roadway where building restrictions afforded opportunity to narrow the sidewalk reservation by relegating trees, etc., to a strip between the right-of-way line and the actual building line—sometimes change these proportions somewhat, but in the main the figures given apply, so that usually a fifty foot right-of-way would mean a thirty foot roadway, an eighty foot right-of-way mean a forty-eight (or fifty) foot roadway, and a hundred foot right-of-way mean a sixty foot roadway. A thirty foot roadway of a city street, i. e., thirty feet between kerbs, is practically the equivalent of the standard state highway with its 18 (or 20) foot pavement and five foot shoulders on each side thereof. This is the minimum width practicable for state highway route traffic nowadays, but the above figures presuppose the roadway clear to traffic. This cannot be insured by this minimum width even now, and not less than forty feet of roadway must necessarily be provided if two lines for traffic are to be left open. A forty foot roadway necessitates a sixty foot right-of-way. A one hundred foot right-of-way, with its sixty foot roadway, would give double the capacity for moving traffic (four ten foot lanes instead of two, beside the two ten foot lanes for stopped vehicles), while an eighty foot right-of-way, with its 48 (or 50) foot roadway, would permit a third lane for overtaking traffic to pass intermittently, but with probably a considerably increased capacity for the roadway or, at any rate, greatly enhanced convenience and pleasure for passenger traffic.

Apparently from the foregoing, a sixty foot right-of-way

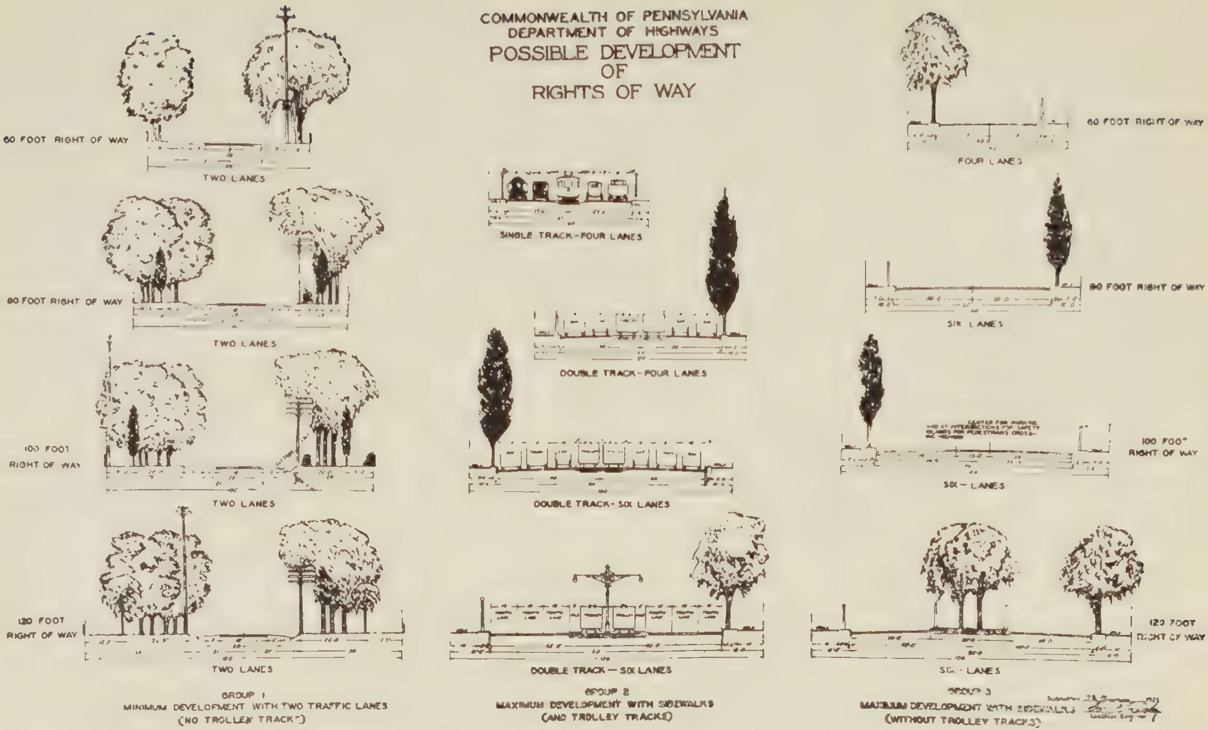


Fig. 19. Sample cross sections to indicate various possibilities for different widths of right-of-way.

will provide ample width for a roadway of a capacity sufficient to carry several times as much hourly traffic as yet observed on any state highway route in Pennsylvania and it is almost the minimum width of right-of-way that should be considered. (Probably the actual minimum, where the ordinary proportions of roadway and sidewalk spaces are to be preserved, is 60 feet, as this will permit a 36 to 40 foot roadway.)

It would also seem that 100 foot right-of-way would supply ample provision for any traffic development reasonably to be expected.

It is probably evident now that the right-of-way widths to be selected are not to be proportioned to the traffic count on the state highways.

As a matter of fact, it is fast becoming more and more generally recognized by highway authorities and the public that other factors than the commercial traffic interests in the highways affect many of the problems, including that of widths.

A thirty-six foot roadway implies a sixty foot total right-of-way as a minimum now to meet the necessities of the present heavy traffic sections of the state highway routes of Pennsylvania, though a sixty foot right-of-way could be made to carry a forty foot roadway. A reasonable regard for the future, with its inevitable increases of traffic, would seem to justify an expectation for a need to increase the forty foot roadway space to at least sixty, which means a one hundred foot right-of-way as a minimum now to be established.

Turning to consideration of those sections of state routes carrying now light traffic, let counts on the Lincoln Highway be taken as fairly representative. Between Philadelphia and Wayne, Pennsylvania, the maximum per ten hour day was 6,684 on September 27, 1924, and the minimum per day was eighty-six (near McConnellsburg).

Apparently the present traffic requirements by no means occupy the capacity of the existing two lane (18 foot) roadway.

As in the case of road culverts, one does not put in a pipe of less than, say, twelve inches diameter—regardless of the needs for waterway—in order to avoid clogging under normal maintenance efforts. Equally, a roadway width should not be established which will not permit traffic satisfaction in spite of only partially controlled parking or other obstruction that may be expected to occur in it.

If parking is to be provided for in the highway, space for it must be contained in the right-of-way width, of course, and in the establishments referred to and in the consideration above it seems that reasonable parking has been included. Unreasonable parking must be avoided or controlled and "commercial parking," i. e., parking for business purposes, must ultimately be assumed as a responsibility by the business interests themselves concerned and taken from the shoulders of the general public and the public highway authorities. In so doing it will probably be advantageous to make greater use of the "third dimension" (height or depth) and less of the "second dimension" (width).

CHAPTER X

THE RECREATIONAL USE OF HIGHWAYS AS AFFECTING THEIR LOCATION

"Now the joys of the road are chiefly these:
A crimson touch on the hard-wood trees;

A vagrant's morning, wide and blue,
In early fall, when the wind walks, too;

The palish asters along the wood—
A lyric touch of the solitude;

And O, the joy that is never won,
But follows and follows the journeying sun;

Delusion afar, delight anear,
From morrow to morrow, from year to year;

The broad, gold wake of the afternoon,
The silent fleck of the cold new moon;

These are the joys of the open road—
For him who travels without a load."

SO, a generation ago, chanted Bliss Carman and Richard Hovey in their "Songs from Vagabondia."

In the rather recent past, a public awakening seems to have taken place as to the value of improved roads for recreational use. Sporadic cases, scattered over the country as a whole, have been recognized in the press. In 1923 the *Saturday Evening Post* had an article or two by A. W. Atwood on the value to localities from tourist-traffic over the roads through them, and in the same year the U. S. National Park Service published some results of their efforts to estimate in one way or another the mass of recreational travel in and around the parks.

Fig. 20. Unobjectionable curvature justified by local conditions.

Atwood had another similar article in the *Post* in February, 1924. The province of Quebec has made some studies in the matter with rather startling conclusions as to the money spent by recreational "voyageurs" over its highways. The state of Michigan has recently carried on some extensive surveys in this connection. And the chamber of commerce of the United States has taken the matter up. Of course, California has for years recognized—at least indirectly—perhaps more fully than any other state how deeply the recreational use of the public highways by motorists affects their road problems of all kinds.

Switzerland has been for years a famous example of the recreational value to a country of good roads even when the use of these roads was confined to pedestrians and to animal

carriage and was less mobile and less popular even than at present.

Now the modern motor car offers a more luxurious means of utilizing the highways for a sort of recreation, and seems to be growing in its effects of appeal to far larger numbers of people for enjoyment of the public roads.

Some motorists, it is true, seem content to drive madly over the roads within a short radius of their homes. Their idea of pleasure seems about on a plane with those of dogs who generally seem to enjoy speeding beyond their own natural powers. But apparently more and more of the motorists travel out over the roads from the cities and towns into the country in search of just such healthful, recreational joys as Carman and Hovey sang. And the proportions of this recreational traffic, while indeterminable precisely, are at least indicated now by the few obtainable figures that may be relied upon.

The Academy of Social and Political Science (Philadelphia) published in November, 1924, a volume on "The Automobile," which, as the foreword, states: "The automobile is revolutionizing American life and American industry." It might also have added "American leisure."

Dr. King does include, a moment later, "recreation" as being affected by the developments, and in the contributed chapters of the volume one may read with interest and profit a concise but suggestive article by M. H. James on "The Automobile and Recreation."

The *Atlantic Monthly* for April, 1925, contained a similarly inspiring and strong article, "Leisure—for What," which deserves study by every public official, particularly highway authorities.

The recreational use of highways is on the increase and should be encouraged for both local and general benefit. Locally and materially, it means increased business, the attraction of new residents, and the development of new or additional industry.

Generally, it means getting city people out in "God's country," with the consequent elevation of ideas of beauty and of what is worth while in life. The body is refreshed by pure air and the mind by clean impressions, both free from the noise, soot and dirt inescapable in cities.

Generally, the appreciation of motor trips through attractive country is high and on the increase. If now, in any case, any inviting surroundings or objective can be added to the call of the trip, it will multiply the popularity of the latter.

The improvement of the public highways and, equally, the development and distribution of the motor, has already greatly increased the radius of action of our vacationists. Further increases are sure to come on both lines. More widespread and deeper appreciation of motoring for pleasure over improved highways is inevitable. It can and should be induced to more rapid and greater development for the sake of both the individual and the nation.

The author is confident, because he has had the good fortune for many years to be able to observe facts along these lines in many countries. Further, for several years he lived among the national parks and forests of the "golden west," and for two years was superintendent of Grand Canyon National Park in Arizona.

It may be interesting to know that a large proportion of all motor travel to this park comes from outside the state of Arizona—even from the "ends of the earth," such as Hawaii and even the Philippine Islands. In fact, in 1923 the motor visitors from outside of Arizona were nearly four to one from the state itself.

Again, the increase of travel to the park by rail has been (roughly) about 6 per cent per year, while the increase of travel to it by motor—over relatively poor roads—is nearer 40 per cent per year.

Were the roads to the park better, the contrasts would be even more marked.

Is it not the duty of the public highway authorities, from whom some considerable vision may properly be demanded, to give serious thought to this matter where opportunity—such as in location questions—offers at the same time as when the factors of the utilitarian or commercial use of the roadways arise?

The faithful state highway department may not escape the responsibility for looking ahead in the interest of the people of the state, and it would seem that it must scrutinize this segment of the horizon as well as the rest of it.

In 1904, the author was engaged in reorganizing the park department of one of our larger Eastern cities. The department had maintained, for a year or so before, a park band whose bandmaster was a butcher. He was a good butcher and equally a good bandmaster.

One day he came to the writer to argue for a higher grade of music at the public concerts. He said he believed it possible to educate the public taste without loss of public support and to their ultimate benefit.

After some discussion, he was told to try. Within a year the level of the music given by this band had appreciably risen, according to the local press, and the popularity of the concerts had proved by the attendance to be greater than ever before. The letters to the newspapers all showed an appreciation of the higher type of selections—gradually, it is true, but none the less certainly.

Many other similar instances might be cited from the author's experience, but one more will suffice for his purposes of illustration. The most severely criticized roads of a certain state today are those whose roadways were built, in spite of his protests, of narrow width, to "give the people what they want" at the time. The wider roadways—where the vision the people perhaps lacked at the time was clear enough to the author for the widths he strove for—have established their superiority before this.

It seems to the author that the demands for scenery—for

natural beauty or attractiveness, for pleasurable roadsides, for protection against encroachment on such features and on the enjoyment of the tourists over the highways that come from light, air, vision, and a sense of freedom from the restricting surroundings of built-up sections—will grow rapidly in the near future. He believes an era of the use of the highways of the states for sane and healthful recreation is opening in all of them and that such use of the public roads of the state is not only a proper function of them, but also one that should be encouraged in every practical way by the state's highway authorities, and, in this connection, particularly by serious and careful consideration of this function of recreational use in all matters of location.

Many times it occurs that the present location of a highway has been brought about by a particularly fine view to be obtained from a point on it, or by some fact of history—such as the passage of Braddock's Army, of the pioneer wagon trains, or of a cavalcade of adventurous spirits.

The road of today may be merely a development of a mere trail which formerly connected localities of importance in history, but now only recognizable as such. This applies with especial force to the longer routes, perhaps. The Lincoln Highway's location was unquestionably fixed as at present largely through such considerations. The Old Trails Highway has been similarly located from Washington to San Diego, and hundreds of others might be cited.

Even within a single state will frequently be found numerous examples of the effects on location by influences which now may be classed as other than economic.

Often it is impossible to evaluate the influences referred to. In some cases attempts have been made to arrive at values for tourist traffic, which may be said to be that portion of all traffic selecting a route because of the connection of these sentimental or cultural attributes with it, but even in these cases the direct relation of them to a location questioned

may be problematical and difficult, if not impossible, to demonstrate mathematically.

The meridian through Phoenix, Arizona, passes very close to Flagstaff, through Grand Canyon National Park, close to Zion National Park, Bryce Canyon National Park, Salt Lake City, Utah, close to Yellowstone National Park, Glacier National Park and not far east of Rocky Mountain Park (containing Banff and Lake Louise) in Alberta, Canada.

Except for the 150 mile section between Flagstaff and Fredonia, Arizona (the entrance to Zion National Park), across the Colorado River and past Grand Canyon National Park, the automobile blue book shows a possible road all the way through the famous points mentioned. One now motoring up from Phoenix has either to miss "the most sublime of all earthly spectacles"—Grand Canyon—by swinging westerly on the Old Trails Highway from Ashfork, Arizona, to Needles, California (150 miles), and then proceed across the Mojave Desert, via Las Vegas, to Zion National Park, or to come east from Ashfork 25 miles to Williams on the Old Trails Highway, and then turn northerly 65 miles on the spur to Grand Canyon; and retrace the run back to Williams and Ashfork, and then proceed, via Needles and Las Vegas, to Zion National Park.

The present location of the roads require approximately a run of 750 miles from Phoenix, Arizona, to Zion National Park if Grand Canyon is to be visited. But if, as has been proposed, a route were located, as it readily could be, by way of Flagstaff and Lee's Ferry (over the Colorado River just above Grand Canyon), the run would be but about 400 miles for the same attractions.

It is beyond the scope of this discussion of location to analyze the economic values of providing a convenient through route for tourists between Phoenix and Banff with the intermediate points mentioned, but the illustration of the effects of other than economic factors on the location of such an interstate route may be pertinent here.

It may be further stated in this connection that the best obtainable estimates agree that not over 25 per cent of the traffic over the Old Trails Highway between Flagstaff and Ashfork, Arizona, now goes up to Grand Canyon. The figures for traffic over the Old Trails Highway in this section of Arizona have not been obtainable, but the total number of motor vehicles licensed in Arizona in 1928 was 97,896, of which 8,877 were "commercial cars."

The following figures from the records of Grand Canyon National Park* show the travel coming there as follows:

	Park years (beginning Oct. 1 previous)		
Origin	1922	1927	1928
Arizona cars	1,554	5,127	4,994
All other cars	6,336	23,352	28,322
Passengers by motors	25,470	89,680	99,303
Passengers by train	59,230	72,509	67,784

That most beautiful of modern roads—the Columbia River Highway—affords a remarkable view from "Crown Point," over which it passes. It probably would have been possible to have carried the road below or away from Crown Point with probably even shorter lines, easier grades, and less first cost, but the loss of the view would have outweighed the utilitarian savings.

Pennsylvania is building a route with wonderful beauties of scenery up the Susquehanna River to Towanda. There exist several opportunities in locating it to save first costs and to reduce lengths and grades at the expense of sacrifices of scenic effects. But the latter are being given every possible consideration in the determination of the location questions.

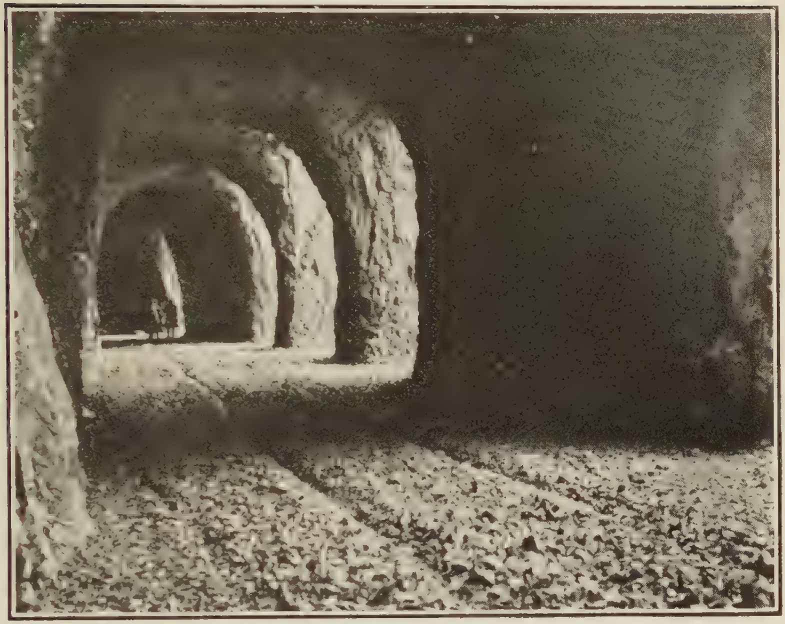
For thirty years—since the acceptance of the principles of state-aid in highway work — outside of the cities — by Massachusetts and New Jersey (in 1893-1894) the city taxpayers have been contributing to the improvement of the country roads. And these days their contributions are enormous, even if the country dwellers themselves are now also sharing in the costs.

*Reports, National Park Service, U. S. Dept. of Interior.

Fig. 21. Columbia River Highway when approaching completion.

It is perfectly true that the road improvements made have materially, if indirectly, benefited the city taxpayer while directly helping the country dweller. But it seems not unfair to invite the attention of the city people to the direct benefits they may now secure from the use of the improved highways for sane and healthful recreational purposes and, in considering highway problems, to recognize the obligation for providing reasonably for the needs of the cities in this respect. This is especially true where, as is so frequently the case, the proper consideration of and provisions for the urban needs equally considers and provides for the rural needs also.

It is not to be understood that the author advocates the building of public race-tracks out of the highways, nor should the pedestrian be considered as eliminated, much as some motorists seem to be trying to accomplish this. Would we



Open Tunnel on Columbia River Highway

had more pedestrians! The nation would be better off. It is not impossible that their development may be induced through encouragement of the recreational use of the highways by starting with the motorists themselves.

Some states are proceeding more or less consciously along the lines suggested by the foregoing when the planting of the roadsides is begun; when width for the future developments of the present roadway is taken; when the protection of the public right-of-way is effected by law or other steps; and when a location question often is decided.

In some quarters highway improvement has been pictured as a sordid proposition for sheer economy's sake. A phrase that has recently appeared quite often as a starting point or basis for argument to prove a conception, and hereinbefore referred to in Chapter III, is as follows:

"No road should be improved by the expenditure of public funds

in excess of its earning capacity. The return to the public in form of economic transportation is the sole measure of the justification for the degree of improvement."

Let us "risk one eye" at some figures indicating whence come now the funds that are available for our road improvements of today. The Bureau of Public Roads of the United States Department of Agriculture has been good enough to furnish the writer with the following figures compiled by its division of control under date of November 1, 1925:

STATISTICAL DATA RELATING TO POST ROAD FINANCES OF UNITED STATES

		Fiscal year ended June 30	Calendar year ended Dec. 31
(1) Grand total disbursements on rural roads and bridges by states, counties, towns, etc.	1923	....	$ 998,052,000
	1924	....	1,072,889,181
	1925	....	1,144,415,513
	1926	....	1,163,747,971
	1927	....	1,283,058,366
(2) Total rural road expenditures by state highway departments	1923	....	448,277,182
	1924	....	596,176,445
	1925	....	649,125,101
	1926	....	621,744,210
	1927	....	699,875,182
(3) Total federal aid post road funds paid to states on completed work	1923	$ 69,667,053	74,883,783
	1924	79,217,398	96,148,474
	1925	95,749,998	90,441,339
	1926	86,754,535	77,727,960
	1927	81,371,013	80,385,906
(4) Gross receipts, motor vehicle license fees, etc.	1923	....	188,970,992
	1924	....	225,492,252
	1925	....	260,619,621
	1926	....	288,282,352
	1927	....	301,061,132

(5) Gross receipts, gasoline tax	1923	....	32,118,529
	1924	....	79,987,142
	1925	106,677,160	146,028,940
	1926	....	187,603,231
	1927	....	258,838,813
(6) U. S. internal revenue from manufacturers' excise tax on automobiles, etc., and parts	1923	144,290,490	....
	1924	158,014,709	139,201,755
	1925	124,686,745	143,430,709
	1926	138,155,194	96,255,639
	1927	66,437,881	60,473,708
(7) U. S. internal revenue from special tax (occupational) on passenger automobiles for hire	1923	1,907,400	....
	1924	2,013,839	1,893,586
	1925	1,865,075	* 1,872,000
(8) Property taxes, motor vehicles by state and municipality, as estimated by National Automobile Chamber of Commerce	1924	....	105,000,000
	1925	....	100,000,000
	1926	....	125,000,000
	1927	....	125,000,000

It will be noted that the motor, in one way or another, supplies a large fraction of all the funds expended on all the rural roads. It is safe to estimate that further analysis would show that state (and federal) highways are being very largely financed by the motor, and that the pleasure motorist—as distinguished from the commercial motorist—is paying the larger part of the bills.

Here it may also be pertinent to admit a ray of light from another quarter just to help the perspective.

". . . . In 1639 a measure was passed in the Massachusetts Bay Colony reading:

*Estimate from 9 months. Occupational tax discontinued.

'Whereas the highways in this jurisdiction have not been laid out with such convenience for travelers as were fit, nor as was intended by this court, but that in some places they are felt too straight, and in other places travelers are forced to go far about, it is therefore ordered, that all highways shall be laid out before the next general court, so as may be with most ease and safety for travelers; and for this and every town shall chose two or three men, who shall join with two or three of the next town, and these shall have power to lay out the highways in each town where they may be most convenient; and those which are so deputed shall have power to lay out the highways where they may be most convenient, notwithstanding any man's propriety, or any corne ground, so as it occasion not the pulling down of any man's house, or laying open any garden or orchard; and in common grounds, or where the soil is wet or miry, they shall lay out the ways the wider, as six, or eight, or ten rods, or more in common grounds.' . . . ."

Historic Highways, pp. 34-35, A. B. Hurlburt.

It seems fairly evident that a better sense of proportion than is shown by the attempted postulation of a single economic axiom for a starting point in this matter is needed.

It has been said that the American people—and hence the nation—lack a sense of proportion. Such may be the fact in this illustrative case—at least, that suggestion is offered.

With at least half the travel on our roads pleasure-traffic (as shown by the various transport surveys of recent years), is there good reason for reducing road improvement—either in programs or in technical details thereof—to a purely commercial basis of monetary profit and loss? Does not "going value" enter also in a way? And what about such scenic attractions as the Columbia River Highway or the Storm King Highway or the "Axenstrasse" or "Corniche" of Europe? Can their construction and improvement be justified solely on "the basis of economic savings in cost of travel" over them? May there not be—in fact, are there not—numerous cases where the opening of a public highway through country where no highway exists is fully justified solely on the ground of making the route available? It may offer no competition with other routes. It may not be economical in any way. But, nevertheless, public convenience and public pleasure or

satisfaction may unquestionably justify the new highway, particularly when the source of the funds for it come, as suggested above, largely from pleasure travelers.

There is one point the author wishes to emphasize further. In arriving at the desirable ultimate width, and in many other decisions for state highway routes, it is to be remembered that provision is being attempted for a considerable future; that the future is likely to be more exigent even than the past or present on this line; that, as before suggested, there are a number of considerations other than vehicular traffic over the roadway to be taken into account; that while roadways are built and maintained for traffic, highways also serve other purposes than the provision of surfaces over which vehicles may travel; that while the width of roadways may properly bear a fairly direct relation to the vehicular traffic, such relation is not as direct when ultimate widths of the public rights-of-way are being determined; and that it is "better to be safe than sorry" in these matters at least. The vehicular traffic bears to the whole right-of-way width perhaps the relation of the skeleton to the body. But the body's usefulness and beauty depends on the clothing of the skeleton with flesh, and many times with even more extraneous adjuncts.

CHAPTER XI

BY-PASSES—ROUTING

"Not how long but how good it is, is what matters."
—*Seneca.*

THE larger view of highway location must embrace the arrangement of highway routes so as to permit —really, *induce*—the use, by through traffic, of roads that will enable this traffic to reach its ultimate destination without the necessity of pursuing the ways in and out of the centers of population or activity that are provided for and bound to be congested by local traffic.

It may first be desirable to visualize for a moment the nature of this through traffic. It will be composed of two main parts—passenger traffic and truck traffic. The former may be subdivided into pleasure and business, but seldom will it be necessary to make that differentiation for the purposes in hand.

For all passenger traffic the advantages of by-passing congested sections will lie in the avoidance of danger (real or apparent), the pleasure of better scenery, and the satisfaction of apparently making better time. If these seem to be enjoyed, the matter of distance or of grades is of little or no consequence.

To the truck traffic by-passes, if they seem to offer relief from congestion, with its dangers and delays, will appeal if again excessive distance and grades are not the price.

The traffic to be by-passed should be again regarded, in the consideration of its routing, as divisible another way into at least two parts. One is that whose origin and destination are located within a relatively short radius from the congested center. Such a fraction will call for a by-pass quite close to the most thickly congested area.

A second fraction would be that traffic coming from a considerable distance and headed for a destination a corresponding distance beyond the center. Such traffic could most readily use a by-pass such a maximum distance out from the centre as would not, in effect, destroy the directness of the main route for this traffic.

Other fractions may be conceived, intermediate between the two mentioned, though circumstances will for the present have to decide how many of these fractions shall be provided for and indeed whether or not any such fractional consideration shall be attempted.

As a general rule, it perhaps may be stated that the importance of any fractions will be in proportion to the size of the congested area, the degree of congestion, and the amount of the through traffic.

Other physical circumstances may affect the problem, such as, in most cases, the topography, the trend of developments in and about the area now to be avoided, and perhaps even the historical, sentimental, or other more or less intangible factors that may enter.

It seems convenient for the purposes of further discussion of this topic, as well as to illustrate that discussion, to refer now to two actual problems in the state of Pennsylvania. In both the cities of Philadelphia and Pittsburgh, downtown traffic congestion has reached the point where police regulation of the traffic over the conveniently available roadways—efficient as both the regulation and the roadways themselves may be—still results in dissatisfaction to the traveler, and with the general belief that this dissatisfaction can but be greater hereafter unless other measures are taken to offer relief.

The maps of Philadelphia and vicinity show the situation there. This city of two million people lies across the junction of the main routes from Washington and Baltimore to Trenton and New York and from Harrisburg, Pittsburgh and the west to Atlantic City and the other popular and widely known

Fig. 22. Philadelphia by-pass study for highway traffic.

seashore resorts on the Atlantic Coast between Long Branch, New Jersey, and Norfolk, Virginia. Lengthwise it is twenty-seven miles from city line to city line, and across the city area is six miles. If we cover the city of Camden, New Jersey, this latter distance will reach perhaps to ten miles, including the Delaware River between the two municipalities.

This roughly rectangular (or elliptical) area with its axes of 27 and 10 miles, respectively, comprises a closely built-up and highly developed section through which at present all interstate travel must pass, with the dangers, discomfort, delay and other interferences attendant upon the co-mingling of through and local traffic, which latter is particularly intense. The area is separated by the river referred to into two parts, physically connected at this writing by four or five ferries at Market Street, Chestnut Street, South Street, Vine Street, all downtown in Philadelphia and at Shackamaxon and at Richmond Street, three miles northerly of the others. Recently the new Delaware River bridge has been opened to vehicular traffic from near Vine (or Race) Street.

At Tacony, Pennsylvania, about eight miles northeast of the Philadelphia city hall, a ferry operates across the river to a point in New Jersey outside of Camden, and there is one from Bristol (about 20 miles from Philadelphia) to Burlington, N. J.

South of Philadelphia, but one operates— from Wilmington (28 miles from Philadelphia) to Penn's Grove, N. J.

There is now no bridge across the river south of Philadelphia nor one north of the cities, until Trenton is reached at a distance of nearly 30 miles.

It is evident that a situation is, or soon will be, established which funnels the east and west-bound, as well as other traffic mainly through the centres of Philadelphia and Camden, with the throat of the funnel or the "bottle-neck" over the new bridge, or at least the bridge and the immediately adjacent ferries. The capacity of the new bridge is expected to be 6,000 vehicles (total, in both directions) per hour, but

traffic studies already suggest the probability of its being severely taxed by the travel coming to it in "peaks."

North and south traffic needs no crossing of the Delaware River until Trenton is reached, but there the line of travel is intersected by the river's course. However, the centre of the city of Philadelphia lies almost exactly on this line so that practically the crossing of the north to south and the east to west travel lines is just where the local traffic is most dense—in the center of Philadelphia.

Already the effects of the existing conditions—above briefly summed up—are appreciable. The cities of Camden and Philadelphia have made some plans for traffic approach to or departure from the bridge and even for by-passing through traffic around the congested center of each city. A group of public-spirited and far-sighted citizens has envisaged the larger problem of providing convenient routes for interstate traffic coming from and going to more distant points so that the regrettable conflict of through and local traffic, where the latter's interests may be regarded as paramount, may be avoided.

It is hoped that, by proper routing, the deplorable congestion within the cities may be relieved and that greater satisfaction to all traffic may be had by a not uncomfortable diversion of through traffic not compelled to penetrate the more crowded sections of the cities, which diversion of it will relieve that congestion appreciably to the benefit of both the local and the through traffic.

In this study the author—as an official attached to the committee—suggested a statement of fundamental principles which has been adopted as follows:

1. The area to be studied has a radius of at least 30 miles from the Philadelphia city hall. (This carries beyond Trenton, New Jersey, and Wilmington, Delaware; more than half way to Reading and Lancaster, Pennsylvania; and half way to Atlantic City, New Jersey.)

2. The by-passing of through traffic past the congested areas of Philadelphia and Camden is essential.

3. In order to bring about an adequate system of by-passing routes, it

is desirable that more than one convenient crossing of the Delaware River be developed within the area.

4. Any such system of by-passing must contemplate easy access from each point of the compass to every other point. This means that the by-passing routes must in effect be concentrically circumferential within the area mentioned.

Inset is a map which illustrates the problem and indicates some suggestions made with the idea of securing some immediate relief and of being toward the eventual solution.

The situation at Pittsburgh, which is in many ways typical of numerous others elsewhere, may be summarized as follows:

From Greensburg westerly into Pittsburgh the Lincoln Highway, so-called, is formed by S. H. Route 120. From Pittsburgh westerly the Lincoln Highway is planned to go over Route 257 to a point on the latter southerly of Imperial and thence via Imperial, Clinton, Cork, Harshaville, Laughlin's Corners (on Route 115) and to the Pennsylvania, West Virginia state line over a recently improved state-aid road and thence over a West Virginia state road into Chester, West Virginia, and Liverpool, Ohio.

Many serious objections to this location, through the congested streets of Pittsburgh and its suburbs, of a heavily traveled trans-continental route are evident, and local relief, as well as relief to the through travel, is being demanded. Looking at this matter in connection with other demands for relief from avoidable congestion from other through traffic, the Allegheny County authorities, in cooperation with the state, have planned the provision of some "belt routes" in that county which will act as intercepters for through traffic, and permit, with but little deviation from the direct course and only slight, perhaps, increase of traveled distance, traffic desirous of passing Pittsburgh to do so conveniently and comfortably for that traffic, and at the same time to the considerable relief of the local congestion in the city.

Inset is a map showing these "belts," of which there may be said to be four: two north, and two south of the city proper. These four are so arranged and combined as to form an inner and an outer belt completely circling the city within Allegheny County and coincident at the eastern and western ends of the diameter through them and the city. It will be noted that this "diameter" is practically the line of the Lincoln Highway for that section.

The improvement of these belts by the county is progressing rapidly.


County of Allegheny
Pittsburgh, Pa.
ROAD DEPARTMENT

Fig. 23. Showing how belt roads solved traffic by-pass problem in Pittsburgh area.

A majority of the actual mileage of them is understood to be in good condition already, but there are some sections of each belt which remain to be improved in order that the belt itself may satisfactorily function as such.

Eventually all of the belt mileage will be needed. It would be convenient if actually complete now. But the immediate pressing need seems to be for the prompt completion of the inner belts and particularly the southern inner arc, which, fortunately, in its present condition is nearest to completion.

Here it should be pointed out that these belt routes of Allegheny County not only offer advantages for traffic passing Pittsburgh, but also facilitate the entrance and exit of traffic into and out of that city.

Taking the southern inner arc above described for illustration, it can readily be seen that the completion of this route (with proper connections as suggested to the state highway through Routes 120 and 257) will offer even better opportunities for outside traffic to reach the city of Pittsburgh itself than now exists.

Serious congestion and obstacles now exist for traffic into the city at Turtle Creek, Greensburg, Westwood, Crafton and Thornburg, not to mention several other points within and nearer the center of Pittsburgh, such, for instance, as the "point" itself.

By taking the inner arc (south), traffic may avoid all these spots where congestion is rapidly growing and where local use fully occupies the limited highway facilities, and proceed to points in the city, if desired, by varous spurs of branches over any of the several bridges crossing the Monongahela River into the residential and business sections.

Similarly the other arcs or belts should help to relieve the situation and eventually should solve the present problems.

According to the county's plans and the present prospects, the completion of the inner northern arc will follow that of the inner southern, and the inner belt will then be completed. The outer northern and the outer southern arcs are expected to follow in that succession.

Other cities or centres in Pennsylvania have similar problems. Altoona, Reading, Lancaster, and even smaller settlements have recognized it.

It should, perhaps, be noted that often, as in these cases, by-passes do not mean many miles of new layouts nor even of new construction, but merely the adaptation of existing routes and, perhaps, even more particularly, their advertisement.

Many have doubtless attempted to follow circuitous

routes, by-passing congested centres, by means of minute descriptions furnished by automobile clubs. Notwithstanding the care taken in the preparation of the directions—usually printed in small type to be compact and usable in a moving car—such experiences have often been most unsatisfactory. The directed turns, when located, often look unattractive or even repellent. Frequently there is great difficulty in identifying the turns from lack of proper street names or other signs, and if one is not proceeding unusually slowly in approaching them the frequent result is to miss the turn that is not obvious. Almost always one emerges from the maze confused and resentful at its lack of clearness, the time required in it, and the missing of the scenery from concentration on the directions, even if thankful for having avoided the congestion known to exist on the more obvious route through the latter.

Even park roads should have a directness apparently consistent with their objective and their meanderings seem justified by circumstances. Scenic roads should be as direct as conditions apparently allow between their objectives, though tangents in neither park or scenic roads may not be called for nor even allowable unless obviously warranted by conditions.

Motor traffic exemplifies a normal human tendency—to "follow the crowd." Many motorists "do not believe in signs." Sometimes they can hardly be blamed for this where the signs are too elaborated, too complicated, and too indistinct for the "runner" to "read." But, on the other hand, intelligent motorists with the purpose of reaching a destination, if fairly advised by legible signs and evident opportunities for avoiding congestion, will watch for chances to leave the crowded line and avail themselves of by-passes that promise advantages.

By-pass departures from the main route must, by the details of their location at the junction, invite traffic, and signs at the point should clearly explain the attraction (see

also the notes on signs). Inconvenient or blind departures will offset any practicable arrangements of sign-posting and defeat the purpose just as a meandering path heading apparently in the wrong direction in the beginning, even though the path eventually reaches the goal, confuses if it does not actually repel travel unfamiliar with it and seeking a destination.

The automobile associations try to help motorists to avoid congestion by printing and distributing cards giving minute directions for the route to be followed around such centres. But reading and following these directions is often arduous and unsatisfactory, often particularly when the reader at the same time wishes to observe the scenery and other interesting things along his route. For such by-passes every effort should be made by location and by simple sign-posting to make the route to be taken as obvious as possible.

Within the past year or two, a change has become evident in the mind of many individuals and in the case of several groups or even municipalities—where formerly there existed a very strong desire, not to say insistent prejudice—to have the improved surfacing of the state highway route laid immediately by the door of the private residence, along the main street of the village or to the central square of the town, there is now considerable support being given by the individual and by the public to the engineer's statement that such location is often most undesirable.

The noise, dangers, and other annoyances of motor traffic, which is largely from other sources rather than of local inception, have converted many laymen to the professional ideas of locating, for the best interests of all concerned, the modern roadway at least a reasonable minimum distance from dwellings, and otherwise than along village streets where local business must be transacted or than through the hearts of the towns.

Large cities now are demanding by-passes for the through

traffic of interstate or similar routes of more than local importance.

Is not the deduction inescapable that future steps immiment in location solutions are those of regarding a certain portion of the whole traffic as through; of determining the termini of this through traffic; and then, as soon as its importance shall so warrant, of locating direct routes for that traffic between these termini, regardless of existing but less direct and therefore unsatisfactory present routes?

Such procedure seems inevitable if traffic developments for the next decade prove to be at all along the lines of those of the last. The consideration may involve regional planning which of itself already threatens many areas of the east, and in its solution again suggests conclusions as to future highway location similar to those above expressed.

It is probably now too early safely to jump to such conclusions, and the location problems of today must still be solved mainly in the light of today's needs. The new position suggested for viewing them must be reached gradually, probably, as in all highway progress so far, somewhat uneconomically but conservatively and safely. The demands of today are for results—imperfect or temporary as they may perhaps be, but actual. And the American public has no compunction about scrapping once useful construction for better whence once the improvement is seen to be justifiable. It may be well, however, for those conducting the highway work to lead it rather than to be driven.

CHAPTER XII

ECONOMICS AND FORMULAE

"Give not Saint Peter so much, to leave Saint Paul nothing." —*Herbert.*

THE economics of highway engineering, so far as they enter the matter of highway location, are those connected with the effects of lengths and of grades of the roadway on traffic operations.

The effects of curves on highway traffic operations cannot now be translated into dollars, for lack of established data, and these curve effects must, for the present at least, be associated with the consideration of safety and of speeds rather than with economics.

The economics of length, i. e., the relative costs of traffic operation over routes of different alignment and consequently of different lengths between any two points, are studied in order to help determine the choice of the alternative locations. These economics are relatively simple. It is logical to postulate: that every mile of distance costs; that the average cost per mile (for distance alone) can be estimated with reasonable accuracy; and that the comparative lengths can be fairly translated into dollars of operation costs for distance or length of route.

It seems quite widely agreed that operation costs for passenger cars should be figured as about ten cents per mile. Some lower figures urged do not seem to cover properly certain unavoidable contingencies, while higher figures are generally regarded as excessive.

In any case, now, where two (or more) routes offer different lengths for the roadway between two points, and the amount of traffic is known or can be estimated, the relative

value of one or the other route is a matter of simple arithmetic. If "Route A" be 1,000 feet shorter than any other, with 1,000 cars per day for the traffic, the operating cost to the traffic will be $6,615.63 less per year than if the longer route is taken.

COST OF OPERATION OF AVERAGE PASSENGER VEHICLE

Depreciation			
Initial cost		$1,200	
Value after 5 years		225	
Total depreciation		$ 975	
Life in miles	50,000		
Depreciation per mile			$0.0195
Tire Cost			
Initial cost per set		$ 90	
Life in miles	10,000		
Tire cost per mile			0.0090
Fuel Cost			
14 miles per gallon of gas			
200 miles per gallon of oil			
Gas at 25c per gallon			
Oil at 90c per gallon			
Fuel cost per mile			0.0224
Interest and Maintenance			
Interest on $1,200 for 5 years @ 6%		$ 360	
5 years' upkeep and overhaul @ $200		1,000	
Total		$1,360	
Interest and maintenance per mile			0.0272
License, 5 years @ $10.75		$ 53.75	
Insurance, 5 years @ $75.00		375.00	
Garage, 5 years @ $90.00		450.00	
Total		$ 878.75	
Cost of license, insurance and garage per mile			0.0176
Total cost per mile			$0.0957

Some argue that the costs of passenger traffic—particularly pleasure traffic—are too speculative or indeterminate to permit

comparisons to be made as above in order to form bases for decisions as to location. It is probably true that most tourists do not consider the costs of motoring a moderate excess, in percentage, of the air-line distance in order to reach their destinations of the day, or of the tour, provided no more objectionable feature draws attention to that excess. But few seem to realize there is any point such as excess cost in such cases where the scenery of the longer road is satisfactory, where its grades seem fair, where its direction is reasonably direct toward the destination, and where congestion or similar obstacles to agreeable speed do not demand excessive time for its use.

There can be no argument on one point. Every foot of length does cost something to travel it. The travel may be worth the cost or it may not. That is another matter. "Time," i. e., delay, or the absence of it, is also another story. The fact is, that lengths can be illuminatingly compared on the basis above indicated by any reasonable allowance for costs of operation per unit of distance.

Where time, i. e., speed of movement, is important, as it is in many cases, the time factor in the costs for length can readily be emphasized. Those who may be interested in this particular matter can find a good illustration of the value placed on "time" in motor operations by referring to the discussion by C. D. Hill and J. L. Crane on the topic of "Increasing the Capacity of Existing Streets," before the American Society of Civil Engineers, and printed in the proceedings of the society for May, 1924, pp. 706, et seq.

Length is not the only factor that may affect the costs or time in operations. Grades, especially steep grades, do so particularly with regard to commercial traffic.

Generally, it may be reasonably assumed, that gradients of less than a moderate maximum (as yet indeterminate) have no appreciable effect on passenger cars rationally designed and in fair condition for use. It is even possible that any such maximum gradient, if now generally agreed upon,

may in the course of a few years be considerably raised, as improvements to the motor develop, even in the case of passenger automobiles.

With commercial traffic, particularly trucks, the maximum gradient, below which it can be safely assumed that the costs of operation are not augmented by the gradient, must be appreciably less.

This feature is more fully discussed under the head of "Grades" in this volume. Let it suffice for the present to quote immediately the formulae of the Pennsylvania Highway Department, used in calculating the relative value of different routes where the lengths and grades are to be considered with regard to the costs of operation of trucks (as distinguished from passenger cars—private automobiles), in illustration of the conclusions and practice of that department when location is under consideration.

The Pennsylvania formulae (and tabulation used) are based on these presumptions.

The costs of operations (for trucks) over grades are materially affected by:

(a) The effect of the grades on the power (or fuel) needed to surmount them.

(b) The effect of the grades toward materially reducing the speed.

Some further assumptions are necessary and those not indicated in the tables may be outlined as follows:

The potential energy of a truck is recovered on downgrades of less than 1.75 per cent.

The potential energy is entirely lost on grades of 10 per cent and over.

The power loss from an idling engine on down grades is negligible.

Only half the total traffic will be adversely affected in the ordinary case by a rising grade, and if there is no acceleration (or deceleration) in giving downgrade, the effect of gravity will only be used to overcome rolling resistance.

COST OF OPERATION OF AVERAGE TRUCK ON 0.0 GRADE

Gross weight of average truck...3,875 tons		
Net load of average truck...1.2 tons		
Life of average truck...6 years		
Depreciation		
Initial cost ...	$3,000.00	
Value after 6 years...	200.00	
Total depreciation ...	$2,800.00	
Life in miles...75,000		
Depreciation per mile...		$0.0373
Tire Cost		
Initial cost per set...	$ 250.00	
Life in miles...10,000		
Tire cost per mile...		0.0250
Fuel Cost		
8 miles per gallon of gas, 75 miles per gallon of oil, gas at 25c per gallon, oil at 90c per gallon, fuel cost per mile		0.0433
Interest and Maintenance		
Interest on $3,000 for 6 years @ 6%	$1,080.00	
6 years' upkeep @ $300 per year....	1,800.00	
6 years' overhauling @ $400 per year	2,400.00	
Total interest and maintenance..	$5,280.00	
Interest and maintenance per mile..		0.0704
Driver's Wages		
6 years—300 days per year—$5.00 per day...	$9,000.00	
Driver's wages per mile...		0.1200
License and insurance—6 years @ $500...	$3,000.00	
Garage—6 years @ $120...	720.00	
Total ...	$3,720.00	
Cost of license, insurance and garage per mile ...		0.0496
Total cost per mile...		$0.3456
Total cost per ton mile—net......		$0.2880

As to the time loss, the attempts to evaluate this may be shown by the following:

COST OF OPERATION
OF 30 AVERAGE TRUCKS ON GRADES
YEAR OF 365 DAYS

BASED ON 30 TRUCKS PER DAY FOR YEAR OF 365 DAYS.
MILES PER DAY EACH TRUCK ------------------------- 41.7 MILES
COST OF FUEL PER FOOT ON LEVEL GRADE --------------- \$0.0000082
OPERATING EXPENSE (EXCLUSIVE OF FUEL) --------------- \$12.60 PER 10 HR. DAY
TRACTIVE RESISTANCE --------------------------------- 35 LBS. PER TON

Rate of Grade	Cost per Foot	Capitalized Cost per Foot	Cost per Mile	Capitalized Cost per Mile
0	\$.71673	\$14.335	\$3,784.31	\$75,686.29
1	.71673	14.335	3,784.31	75,686.29
2	.72314	14.463	3,818.17	76,363.37
3	.75014	15.003	3,960.72	79,214.34
4	.79294	15.859	4,186.71	83,734.27
5	.85540	17.108	4,516.52	90,330.43
6	.92710	18.542	4,895.09	97,901.76
7	1.00531	20.106	5,308.02	106,160.42
8	1.09401	21.880	5,776.39	115,527.83
9	1.20681	24.136	6,371.97	127,439.35
10	1.29193	25.839	6,821.39	136,427.78

Summarizing the foregoing in convenient tabular form for use in comparing different locations on the bases of lengths and grades for truck traffic, we have:

It is clearly recognized that the conclusions so far reached here are not by any means beyond criticism. But in absence of anything known to be better, they are used for most cases

SAVING IN OPERATION EXPENSES OF A TYPICAL TRUCK BY ELIMINATING 1 FOOT OF RISE AND FALL WITHOUT INCREASING DISTANCE

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Rate of Grade	Acceleration due to gravity parallel to the grade in #/ton.	Tractive Resistance in #/ton.	Force wasted in #/ton.	Wasted force in % of Accelerating force along grade.	Level Distance Equiv. to wasted force per ft. of Rise and fall. *	Fuel waste per foot of rise and fall expressed in dollars	Average Speed in Miles per hour.	No. of Minutes required to travel 1 Mile.	Time in Minutes required to travel 1 foot.	Time lost in minutes per foot of distance due to grades.	Time lost in minutes per foot of rise & fall.	Value of lost time per foot of rise and fall expressed in dollars.	Total increased cost of operating a truck due to 1 foot of rise & fall.
0	—	35	—	—	—	—	12.0	5.0	.00095	—	—	—	—
1	20	"	—	—	—	—	12.0	5.0	.00095	—	—	—	—
2	40	"	5	12.5	357	.0000293	12.8	4.7	.00089	—	—	—	.0000293
3	60	"	25	43.3	12.4	.0001017	12.3	4.9	.00092	—	—	—	.0001017
4	80	"	45	56.25	16.1	.0001320	11.0	5.5	.00103	.00008	.00200	.0000420	.0001740
5	100	"	65	65.0	18.6	.0001525	9.5	6.3	.00119	.00024	.00480	.0001008	.0002533
6	120	"	85	70.83	20.2	.0001656	8.2	7.3	.00139	.00044	.00736	.0001546	.0003202
7	140	"	105	75.0	21.4	.0001755	7.0	8.6	.00162	.00067	.00957	.0002010	.0003765
8	160	"	125	78.1	22.3	.0001829	6.0	10.0	.00189	.00094	.01180	.0002478	.0004307
9	180	"	145	80.6	23.0	.0001886	5.0	12.0	.00227	.00132	.01470	.0003087	.0004973
10	200	"	165	82.5	23.6	.0001935	4.5	13.3	.00253	.00158	.01580	.0003318	.0005253

*½ Traffic moving each way.

ASSUMPTIONS

Truck Weight - Gross 3 875 Tons Ave Net Load 1.2 tons.
Tractive Resistance 35#/ton.
Fuel Cost per foot $0.0000082
Operating Expense (exclusive of fuel) $12.60/10 hour day

in Pennsylvania where relative and not actual values are now the desiderata.

Further, it is frequently the case that the economics of a location are now only a part of the basis on which a decision of choice rests. In the matter of highway location, as before suggested, many considerations now enter that tend to submerge the economic factor, or at least to alter the outer form and perhaps the entire aspect of the questions to be settled for the benefit of the public generally. The economic skeleton of the problem—body should exist and for it the comparative valuation obtained as above seems at present reasonably sufficient, even though it is not as actual as might be desired nor as probably will be demanded in the future.

It will be noted that a regard for the future has entered into the Pennsylvania calculations. From the amount and character of the known present traffic in each case, an estimate is made of the average traffic probable on the road during the

next twenty years. The period is chosen as a convenient one within the life of the bonds furnishing the funds for the work. The first costs of the work, amortized in the twenty years, the interest charges, and a liberal allowance per year for maintenance are all included as "fixed charges," along with the estimated costs for actual operation of the vehicles estimated to make up the operation costs on the road.

It is well known that traffic is attracted to a road by the improvement of the latter, and experience has shown that within five years the traffic over the improved road is usually double what it was before the improvement. There is also a constant yearly increase in numbers of cars over the improved main roads, the figures for which increase or vary more or less, perhaps, in different localities, but seem to average 20 per cent yearly now.

It has, therefore, seemed conservative to estimate in Pennsylvania that with the improvement of a section of the primary state highway system the present traffic will be doubled in five years thereafter and average double the present traffic for the twenty-year period.

Pursuant to the foregoing, the Pennsylvania Highway Department has developed a form of report for summarizing the facts, in the matter of a comparison between two possible locations, for an improvement of the section of state highway in question, which form (P. H. D. No. 468, filled in for a typical fairly simple case) and report, to illustrate the text, are shown in attached "Appendix A." (See also Chapter XIII).

As suggested (p. 106) the "increase in number" of highway vehicles "goes much deeper than the single function of providing room" (see "Widths").

The increase in numbers has, on the whole, been caused partly by the transference to the highways of business traffic heretofore carried by rail or waterways and its corollary, the development increase of such business, or this feature of it.

Just how deep, wide, or intricate and influential the rami-

fications of this increase in numbers of highway vehicles may become, with its comprehended changes and developments in business methods of goods transportation, cannot now be accurately forecast, if even clearly distinguished very far.

It will be generally admitted, however, that the effects are already apparent in many places and ways, and that they probably will be epoch-making.

There are many instances already where it has become at least economically desirable to provide new roadways or routes for business traffic segregated from pleasure or mixed traffic. Industrial highways loom within the present horizon. Again, the by-passing of a large portion of the traffic over a through route, so as to avoid congestion, danger, discomfort, and even economic loss where through and local traffic conflict in populated foci, is a pressing problem today.

Is not a conclusion now forced on the student in highway engineering or in economics as related thereto, and should not that conclusion be recognized and its demands anticipated?

Our public highways are not often located economically for even present day needs. Are the present locations likely to prove more satisfactory in the future?

Anyone who has been in touch with public highway work for a few years knows how often a demand comes for a change of alignment or a regret appears that an improvement of the old alignment was not made when the surface of an old roadway has been modernized. And all know the tendency of new highway authorities to suggest changes of alignment for various reasons—some of them economic. While the alignment improvements just referred to are usually minor, the suggestion is inescapable that they forecast greater revisions of the old locations.

As the main highways of a state become superficially modernized on their old locations and as traffic increases and developments progress, it would seem fairly certain that an early successive event will be a resistless demand for the

more economic location of some of those highways. Already some "shadows" are "cast before."

Industrial highways are being proposed for purely commercial purposes to replace circuitous or badly graded old roadways, with entirely good surfaces, between foci of population not farther apart than the present recognized radius of economic truck operations, i. e., say 30 miles. The not distant future may even extend this to 100 miles.

By-passes of cities are already a reality, as are purely scenic and recreational routes. In fact, the propriety of the old highway locations, on which modern road surfaces have been placed or are proposed to be placed, has been suggested often and in many ways to be questionable. But it seems too often that this matter of the propriety or insufficiency of the old location in the light of even present day traffic and its tendencies that are already apparent has been neglected by those to whom the public has to look to keep in advance of the procession.

It is entirely probable that under the pressure for results on the road surfaces, future problems or even deeply underlying conditions have had to be overlooked or ignored in the past. Can that defense now be put forth for continuing an ostrich attitude?

Traffic studies have been widely carried on and discussed. Preparations have been made in construction details (of road surfaces) to meet conditions anticipated and generally concluded as imminent from these traffic studies. But there seems to have been, as a whole, very little thought given to research and study of the theories or principles of highway location, yet it would seem here was a considerable field across which highway engineers must very soon make their way with the usual pressure on them for speed and economy in so leading the results.

The proceedings of the National Research Council's Highway Research Board show their program and committee work cover some important superficial features of highway

engineering, such as "Structural Design of Roads," "Character and Use of Road Materials," "Highway Bridges," and "Maintenance." There are three other committees covering broader ground—"Economic Theory of Highway Improvement," "Highway Traffic Analysis," and "Highway Finance."

It might be expected that a fundamental of such depth as location would be comprehended in the field of one or more of these three latter mentioned committees, but study of their reports does not indicate that any one of them is considering this factor in highway engineering seriously, if at all.

The particular subject is, perhaps, touched by the committee on economics under "Grades"; approached under "Costs" (though the confinement of the committee's consideration to costs as affected by superficial factors is noticeable) and possibly touched again when "Lengths" are mentioned. One reads the report of the committee on highway finance and wonders how the subject of location was so completely avoided. It seems concerned entirely with the financial aspects of surfacing our existing highways. And one speculates as to why some suggestion was not proposed along the line of contemplating some relocations of them in the interests of eventual economy for the public.

The report of the committee on highway traffic touches more definitely, if only lightly, some location matters, such as widths (though the context is mainly restricted to the width of the roadway surfacing); and a recognition of location may perhaps be inferred from some of the other parts of the report.

If this highway research board is fairly representative of American Highway Engineers as to their conception of highway problems, it can but be evident that there is now a lack of regard for a problem of fundamental importance to highway engineers and the American public—that of proper locations for the public roads, particularly those for whose im-

provement and maintenance the dependence must rest on the state at large.

It is not to be inferred from the author's remarks along this line that criticism of anyone is intended for any failure to this time to include more clearly location investigations and discussion than has been done. Nor is it intended to suggest even that extensive scrapping of our old locations shall take place.

But it is the purpose of the author to suggest that we cannot safely defer much longer the study and clarification of highway location principles. Already the industrial highways numerously proposed reveal a criticism of present locations for some conditions, and there seems to be very little professional agreement of thought as to the worth of those suggestions for relief or as to the principles on which any relief should be based.

Criticism of legislative location has often been scathingly offered. We must probably envisage now the actual situation of the near future when the legislative location of highway routes will be made with consideration of engineering opinions on the suggestions being considered, even if we are not soon called, professionally, to exercise a critical and conclusive judgment. Preparation to meet these demands should no longer be trifled with. Let us cooperatively "do it now."

With every state highway department there is annually a great deal of pressure for mass production. That is, the official heads are ambitious each year to establish a record for mileage of new construction; the public clamors for mileage of new and better road surfaces.

Inconsiderate yielding to these demands has always brought regrets.

When California began her state road improvement work some fifteen years ago, and an $18,000,000 bond issue was voted for it, the public demand was for prompt results on the surface of the mileage. The highest possible mass production was publicly demanded. Consequently, it was neces-

sary to establish standards with the utmost regard for economy per square yard of surface and without involving avoidable expenditures in time or money for the consideration of any extraordinary peculiarities of the individual section of road. Ten years later, the administrative officials responsible for the results then in evidence were inordinately criticised for what was charged as a lack of technical ability rather than for a perhaps mistaken policy, and it may be questioned if the criticism should not have been entirely on the policy and against the public demands.

Almost every state highway department of any long standing finds itself now in a similar position. In every state one finds numerous laymen who properly ask, more or less forcibly, "When they were putting down this fine surface, why on earth didn't they take advantage of the opportunity then offered to take that kink (or pitch) out of the roadway?"

It may be perfectly true, as Ian Hay puts it in effect, that the American temper considers anything, no matter how satisfactory when new, in a few years obsolete in design, though by no means worn out as to material, and proper for the scrap-heap, and that our whole system of public expenditures is on this basis. This may apply to our modern roadway work. He says that, "In England they are then just beginning to award it that measure of toleration and respect due an institution which has justified its existence and proved its worth." It would seem as though the time had now come when, as before suggested, perhaps, the trained highway engineers at least should, in the light of professional developments during their experience, regard seriously the prospects of the future as well as the records of the past, and, resisting the temptations to acquire reputations on the quantity basis, endeavor to improve the quality of their work not only as regard the comments or metals and their products but also as concerns that important fundamental—location.

Does not the American temper referred to by Hay* con-

trovert the principles of most Highway bond issues if it is indulged to the extreme of temporary or insufficient designs?

"British humor is like everything British: it must stand the test of time to gain acceptance. Our jokes are like our locomotives and motor cars: we take infinite pains over their design, material, and construction, and we expect them to last a lifetime. Usually we are not disappointed.

"In America they take the opposite view. America cherishes a theory that it is useless and wasteful to put too much material into any mechanical contrivance—and what else is a joke but that?—because the design will be obsolete before the material has worn out. So America has given us the rapid-fire topical jest and the Ford car.

"That is the essential difference between our two nations. In America, after a thing has lasted for a certain space of time—be it a law, a jest, or the kitchen-stove—it is adjudged to be out of date and goes to the scrap-heap at a moment in its existence when we in England would just be beginning to award it that measure of toleration and respect due to an institution which has justified its existence and proved its worth."

For the present the main activities of federal, state, and county highway authorities cover the surfacing and incidental improvement of general purpose roads. These roads will render essential service to the localities they pass through and to the general public. They will also afford convenience and comfort to a proportion of the traffic greater than one-half of all the vehicles using them. Further, these improved roads will offer means of healthful enjoyment to all their travelers. Consequently all these functions—not simply one of them—must affect the location and improvement of the highways mentioned.

There comes now occasionally a peculiar case—and the occurrence of these extraordinary cases may be on the increase. Two, not too widely separated, communities develop intimate commercial relations. A need seems to arise for highway communication between them which shall be particularly for business use. Such a case is illustrated by Philadelphia and Chester, Pennsylvania, (whose city limits are about eight miles apart) where it is proposed to improve an industrial highway purely for commercial use.

*"The Shallow End" (often much deeper than we think) by Ian Hay.

In this instance it may be proper to let only the commercial interest decide the questions of details for this roadway.

Antithetical circumstances may predominate and the road be solely for pleasure traffic—such as the Pike's Peak road or the Weatherford Road to the top of the San Francisco peaks, or numerous roads for similar purposes in the national parks and elsewhere.

Both these are peculiar types for extraordinary conditions, and must be treated as such. The importance or frequency of either or of both may change the rates of such today, but at this writing it seems not extravagant to regard these cases as abnormal and that the normal cases are, as mentioned, the general purpose roads.

CHAPTER XIII

LOCATION PROCEDURE

"Let no act be done without a purpose, nor otherwise than according to the perfect principles of art."
—Marcus Aurelius.

WHILE different laws, of course, require different procedure in location matters, it may be interesting and illuminating now to summarize and to illustrate by a specific case the *modus operandi* of the Pennsylvania Highway Department as developed by the author.

The state's legislation has already established (by selection) or located some ten thousand miles of public road in the state as a state highway system and placed the responsibilities for the improvement and maintenance of that system in the hands of state authority (the secretary of highways) for the commonwealth.

The legislature numbered and described each individual route similarly to the following specific case:

"Route one hundred and fifty-three. From Philadelphia to Allentown. Commencing at a point on the boundary line of the city of Philadelphia, near Chestnut Hill; thence running by way of Fort Washington, Springhouse, Montgomeryville, and Colmar to a point on the dividing line between Montgomery and Bucks counties; thence to line Lexington, Sellersville, Rockhill, and Quakertown, to a point on the dividing line between Bucks and Lehigh counties; thence by way of Coopersburg to a point on the boundary line of the city of Allentown, Lehigh County."

The old road—identifiable by the above description—has been marked on the published maps of the department as a primary state highway route.

As before quoted in this book (Chapter III), it is held by the legal authorities of the state that the highway department must improve or maintain the route (in this case, between Philadelphia and Allentown) as identified by the legislative

Page 151 attaches here.

Fig. 24. Route, controls, and topography of Philadelphia—Allentown Line Problem.

Page 150 attaches here.

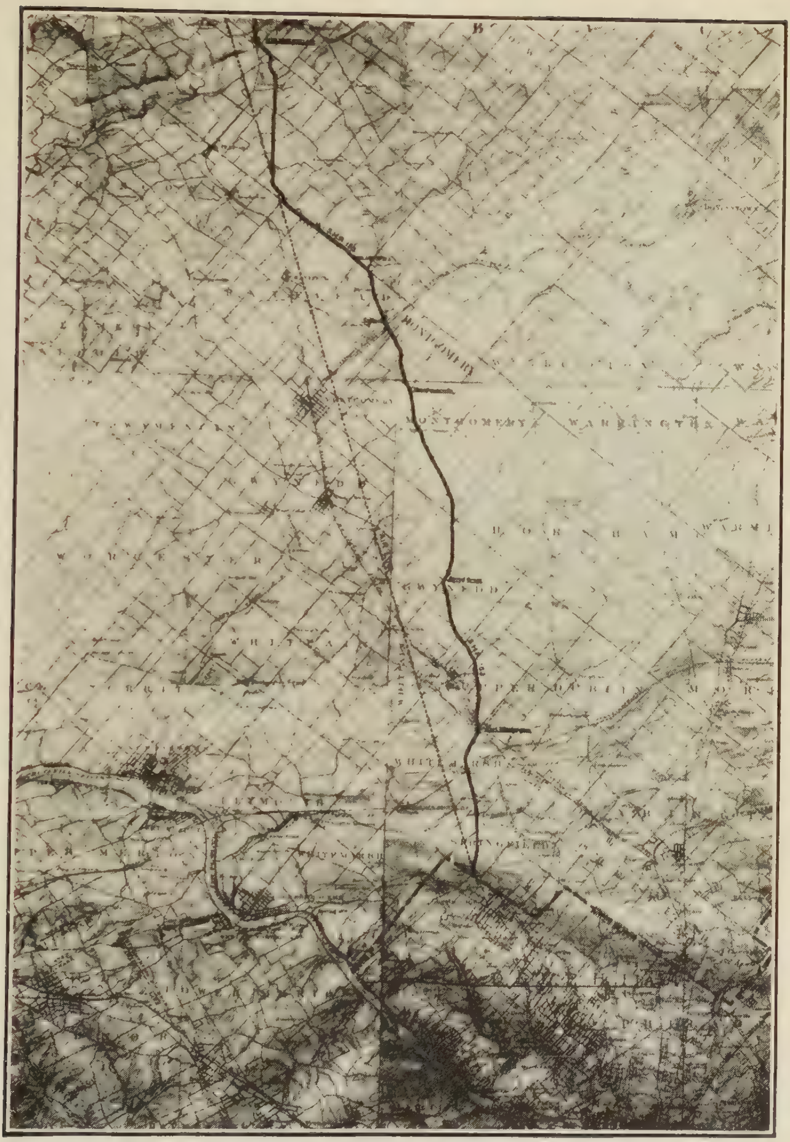


Fig. 24. Route, controls, and topography of Philadelphia—Allentown Line Problem.

description, though the improved roadway may vary from the original or present public road or right-of-way between those points, *provided that,* if the new roadway shall be relocated so as to by-pass the intermediate villages or boroughs named, a proper connection or spur shall be provided by the state between each of these settlements and any relocation for the state highway.

Now in this case it appears that previously a modern paved roadway has been provided along the right-of-way of the old road from the point of beginning of the above legislative description for 7 miles to Springhouse en route to Allentown (40¾ miles from Philadelphia) and that this roadway is satisfactory to the present requirements on it. From Springhouse to Quakertown (20 miles) the present roadway is in such condition as to be reasonably sufficient for the present and no improvement is contemplated by the state this year for this section. However, the existing roadway of the established route from Quakertown to Center Valley (7¾ miles) is in such condition that its resurfacing must be done by the state at once. From Center Valley to Allentown (6 miles) the existing road (recently improved) may be regarded as lying outside the present consideration.

The question that first arises, therefore, is as to just what location or alignment shall now be contemplated for the section of new roadway now to be provided for this route on the fraction between Quakertown and Center Valley.

Philadelphia, the third city (in population) of the United States, is, of course, a large center of production and consumption. Allentown is a growing center and, with Bethlehem less than five miles away, forms an important region for production and consumption. The distance (40 miles) between the two regions (Philadelphia and A-B) is well within the radius of efficient motor-trucking operations over a direct connection by improved public highway. Such operations demand several provisions to be made properly—directness; avoidance of unnecessary length or excessive curvature

and grades; sufficient width; avoidance of local congestion and of danger, together with proper regard for local convenience and use of this route, which for the present, at least, must be regarded as a general purpose highway.

It therefore seems unnecessary, before the propriety of the present location of a section of the entire route can be determined, first to examine the route as a whole.

The transport surveys (of 1923 and 1924) show the following figures as regards the traffic use of this route:

TRAFFIC COUNTS—1923

Location on route	Average Sunday total	Average daily total	Average daily trucks
At Chestnut Hill	4,402	2,552	505
Near Valley Creek	3,758	2,014	404
At Springhouse	3,710	1,650	338
At Montgomeryville	2,930	938	154
Near Sellersville	2,653	1,003	145
At Rich Hill	2,811	1,230	135
At Quakertown	2,857	1,168	139
At Coopersburg	3,127	1,430	291
At Allentown	2,816	1,878	367

TRAFFIC COUNTS—1924

Location on route	Classification	Average daily traffic Summer	Winter	Average
Near Springhouse	Trucks	129	115	122
	Passenger cars	1,573	727	1,150
	Total	1,702	842	1,272
At Sellersville	Trucks	155	113	134
	Passenger cars	1,373	730	1,052
	Total	1,528	843	1,186
Coopersburg	Trucks	208	158	183
	Passenger cars	1,679	1,013	1,346
	Total	1,887	1,171	1,529

It is apparent that the route may be regarded (relatively, at least) as a heavily traveled one, and one on which future traffic is to be much more severe and numerous within the life of the most durable roadway now proposed to be built.

The improvement of the roadway will accentuate these conclusions.

The present alignment of the route between the termini —and in some cases between the intermediate points mentioned in the act—is somewhat indirect and thus unnecessarily long; the grades on the present alignment are more severe than are now or likely to be satisfactory; and congestion and dangerous situations for all traffic exist at numerous places along the present alignment. Discomfort, dissatisfaction and inconvenience also are suffered by the residents along the present roadway from the conflict of interests between the through or foreign traffic and the local enjoyment of the roadway.

Reference now to the map showing the route, its controls, and the topography reveals the following:

An "air line" from the "centre of gravity" of Allentown and Bethlehem to Philadelphia passes through or close to Centre Valley. This latter point is in a gap in the hills through which the route must come from the south into Allentown and Bethlehem, and it also forms a convenient point for diverging from the air line by Y's or branches to the individual centres of both these towns, which are about five miles apart and each practically the same distance from Centre Valley.

From Centre Valley southerly to Philadelphia the air line would pass east of the present location in the village of Coopersburg; through Quakertown; a little west of Rock Hill, and of Sellersville; be nearly coincident with the present location at the Bucks-Montgomery County line, and then lie to the west of Line Lexington and of the present route through Colmar, Montgomeryville, Springhouse, and Fort Washington, to coincidence again at the Philadelphia city line.

It has been noted that a modern roadway satisfactory for present needs exists south of Springhouse and that the existing roadway seems satisfactory for the present below

Quakertown (to Springhouse). The present problem is, therefore, the location above Quakertown to Centre Valley, both these points being coincident on the present route and the air line. Whatever the future may hold for relocation below Quakertown (to Philadelphia), evidently no consideration of that section need now be included on the section from Quakertown to Centre Valley.

Within the limits so arrived at for study as to improvement now with a durable type surface (i. e., between Beaver Run, south of Quakertown, and Centre Valley), the air line is 6.65 miles, or a mile less than the length of the present road. This air line appears impracticable, as it cuts Quakertown and Coopersburg diagonally, which would cause excessive property damage and also introduce difficult and dangerous traffic conditions due to passing through main streets of the boroughs. It also introduces two railroad crossings with consequent problems and complications; does not fit the topography to advantage; creates a duplication of nearly parallel roads in certain sections; does not serve rural interests to advantage, and would cause excessive property damages.

The approximate air line (6.85 miles) shown on the map not only encounters less physical obstructions, avoiding entirely the railroad crossings, but also offers better construction possibilities with light grades and good alignment; makes use of about 3 miles of existing public highways and seems to comply with all the requirements of the legislative act creating Route No. 153. It, therefore, appears to justify further study in detail.

A study of the topographic maps available and covering a section between Rich Hill (just south of Quakertown) and Centre Valley enables a suggestion to be made for a relocation on an approximate air line between these points that will offer many advantages along the lines indicated above as desirable, such as greater directness, shorter lengths, better grades, avoidance of congestion, and other dangers to

traffic. The relocation so suggested will also bring this section of the route very closely in alignment with the most direct route needed between the termini of Philadelphia and the Allentown-Bethlehem region, so that its improvement would seem to form a real step toward what may be considered as an ultimately desirable establishment, though for some years to come the rest of the establishment may not be completed and the present character of the highway as a general purpose one, but not a special industrial highway, may be retained and that function of it served.

A preliminary field survey of the suggestion developed from the maps was therefore authorized, and was made by the district engineer's forces. His report shows the following in support of a relocation proposition:

"Either of the locations shown on the attached print is in conformity with the requirements of the existing legislative act establishing this route.

"Scenic and similar considerations on the proposed relocations are equivalent to, if not better than, such features along the present route location.

"The proposed location will avoid, for through traffic, one grade and two half grade crossings with the Lehigh Valley Transit Company (Liberty Bell Route) which exist on the present location of the route. However, the relocation will require the creation of a new grade crossing with the Lehigh Valley Transit Company at a point to the northwest of Quakertown Borough. The present route, through the latter place, parallels the trolley tracks and consequently there is created a rather undesirable congested traffic condition along the present narrow built-up street (33 feet between curbs). The relocation avoids this unsatisfactory feature entirely.

"The character of the country traversed by the relocation is mostly farming land and low land. Between the termini of the two locations there are 13 houses and 2 schools along the relocation, and 143 houses, 5 churches and 2 schools along the present route. In addition, either of the locations serves Coopersburg (89 houses) and Quakertown (97 houses).

"The length of the present route is 52,712 feet or 5,012 feet more than the length of the relocation (47,700 feet), which is an appreciable saving in favor of the latter on this important primary route. It will further be noted that the relocation as proposed conforms very closely to the ideal air line location between Centre Valley and Rich Hill.

"The maximum grade on the present road is 7.94 per cent, which extends for a continuous length of 1,025 feet, whereas on the relocation the maximum grade will not exceed 8 per cent (length, 600 feet).

"The proposed line, in Quakertown Borough, will avoid an exceptionally sharp curve in a narrow and built-up section. This undesirable and dangerous condition that exists along the present route cannot be modified sufficiently satisfactory without involving excessive property damages. Alignment along the relocation is a vast improvement over that along the present route, the maximum degree of curvature being one nine-degree-and-thirty-minute curve as against a maximum of three fourteen-degree curves on the latter (excl. of the 60° curve in Quakertown Borough).

"It is estimated that the cost of construction on the present location would be $424,385 or $16,241 more than the estimated construction costs via the proposed relocation ($408,144).

"The present daily traffic is reported as 1,346 passenger cars and 183 trucks. The probable future daily traffic is estimated as 2,700 passenger cars and 400 trucks. Predicated on the latter traffic figures, the economic formulae of this department show the following annual operation costs:

	Present route	Proposed relocation
Passenger cars	$941,654	$852,026
Trucks	531,195	476,552
	$1,472,849	$1,328,578

or an annual saving of $144,271 in favor of the relocation.

"The value of the land traversed by the relocation is about $125 to $200 per acre for farming land and about $50 per acre for marsh land, I am informed. The total land damages involved in obtaining the necessary lands for ultimate right-of-way purposes on this location would amount to approximately $15,350. In addition, the moving back of buildings to obtain a 100 foot right-of-way would involve about $12,300 on the relocation. The average value of the land necessary to widen the present road to a 100 foot right-of-way width with the incidental minor line revision is about $150 an acre, involving total land damages of $12,300. Property damages on the old location, because of the built-up conditions now prevalent, would amount to about $285,600 in order to obtain the prescribed ultimate right-of-way width. Hence damages would be about $260,000 more along the present location than via the relocation.

"No abnormal maintenance conditions nor unusual construction difficulties would be encountered along either of the locations considered."

From the foregoing the Location Engineer recommended to the Engineering Executive the approval of the relocation for the roadway improvement now contemplated on this route.

CHAPTER XIV
AFTERWORD

IT is entirely possible that many authorities within this generation will not have problems of extensive physical relocation of highways to be solved and that their efforts in this connection will be limited to questions of line revision on a rather small scale. However, even those latter will involve to a proportionate extent the same fundamental principles and require the application of proper theories, just as do the large problems of location, if satisfactory solutions are to be expected.

It is to be hoped that the political locating of the past may soon be superseded by more efficient and more rational locating or selecting hereafter.

Scientific solutions of the problems of location must first be sought for and reached free, as far as possible, from indeterminate factors to which only fanciful values can be assigned. In most cases a purely mathematical answer may not be obtainable free from a factor of "popular approval," to which it is always so impossible to assign a real value. In the smallest cases of line revision there is always some individual interest that insists on consideration. In cases of relocation for a mile or more, the personal interests increase or multiply relatively; and in the larger cases of relocation or new location this factor usually has proportionately grown to community size.

In the opinion of the writer, the best rule for dealing with this imponderable factor of popular approval—and, in fact, the only one for an engineer or other highway authority whose ambition is not for political success—is to eliminate it ruthlessly as fast as it appears in the integration or reduction of the equation and to depend solely on the other numerical and impersonal factors for arriving at an answer.

In matters of highway location, as in so many others, popular approval is a "will o' the wisp." Professional approval of one's work is more substantial and valuable. But self-approval through an enlightened and contented conscience is, after all, one's most gratifying and enduring reward.

As stated in the foreword to this volume, accomplishments are what is expected of highway engineers. When the funds have once been provided the public looks with the utmost impatience for results that it can use.

The demands for mass production, that is, the pressure for annual mileage of accomplishments in both contracts and completed road surfaces, have not permitted the proper study of every case nor even the thorough and complete study of many cases of location problems. It is the old story of quantity vs. quality. The natural conflict between the impatience of the public or the desires of the responsible authorities make records in mileage of improved roadways and the inclinations or needs of the scientist or technician for time to analyze, consider, digest and calculate or conceive results satisfactory from his points of view seem likely to be present always; hence the needs before referred to for foresight, imagination, decision, and forcefulness of a good executive in location matters.

According to American ideals and practices in so many other matters, the public is entitled to prompt results—the best immediately available, even if not perfect—and the privilege of abandoning those early results as soon as it is ready to pay for better ones.

The morality, economy, or propriety of this American attitude is not the point of the moment here. What is in the mind of the writer is that results in highway location cannot be deferred for the development or perfection of theories at the moment not established for changed or changing traffic conditions. The efforts must be made to catch up, but in the meantime actual results must be had even if they are

in turn thrown away when something better offers or is needed.

Reason would often seem to dictate the improvement of old highway locations with minor changes in them for prompt results and early gratification of present traffic, rather than delayed large relocations and disturbance of traffic habits for the sake, perhaps, of ultimately better satisfaction to possible future traffic developments.

While here and there conditions seem to be suggesting the desirability for purely industrial roads, the ordinary and most usual circumstances as yet justify only the improvement of general purpose roads. On these roads pleasure traffic must be given as much consideration as through or business traffic.

Reviewing the past it is not hard now to visualize further development of conditions within a relatively few years, which will in numerous instances require the location and improvement of purely industrial highways, and perhaps a fairly extensive system of such highways may eventually be required in certain parts of the country. When the time shall come for the establishment of numerous industrial highways, it will quite likely be agreed that their cost for rights-of-way and for construction and maintenance shall be borne by the industries and not under the present system, which inclines toward putting the costs of improvement of the general purpose roads so largely on the motorist as distinguished from the industrialists.

It may be true that the present curving, somewhat indirect road between two foci of traffic can be shown to be uneconomic in location when compared to a straighter and somewhat shorter location possible now at equal or slightly greater first cost for the results in roadway standards of today. And it may even be that, on the basis of reasonable expectations for commercial traffic between the termini of the case, the savings figureable for operation costs will more than

offset the amortization of any extra first costs of the relocation.

Still the author feels that even such relocations should be determined now only after full consideration of all the other factors that, as he has tried to show herein, are involved. And he feels conservatism, as to relocations purely for estimated economic benefit, should clearly rule the decisions in all cases where a serious disturbance of general transportation or social conditions would certainly result or where the traffic to be provided for is evidently now not less than, say, "99 4/10 per cent pure" commercial business traffic nor is likely in the future to be less than mainly truck traffic.

As a final conclusion, the author feels it proper to remark that good location at justifiable first cost is to be preferred to inferior location at less cost. Ben Franklin expressed the idea with his usual forcefulness when he said, in effect, that "It was not so disappointing to realize that he had paid a high price for something as it was to find he had bought, at any price, something he did not want."

BOOK II

Notes on Mountain Highway Location

BY

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INTRODUCTORY

THE academic or discursive nature of Book One is fully recognized by its author. He intended the title chosen for it to indicate this.

The engineering solutions of many of the general problems covered in the "Notes on Highway Location," as well as the specification of the problems themselves, may be best presented by consideration of cases where many, if not all, of the important features are accented, or abnormally emphasized, when compared to their situation in the more usual case.

Mountain highway location, even in its ordinary cases, usually comprises many factors of special importance, which, even when included properly in location work in flatter country, are too frequently allowed to be disregarded or submerged there by other temporarily and apparently more pressing considerations. Hence, by detailing some of the problems and their solution in a book on "Mountain Highway Location," it seems that the illustrations desired for some, at least, of the problems that underlie all highway location may best be had just as, in platting for study the profile of a highway, an exaggerated vertical scale is used to bring out clearly the unevenness of the ground and its effects.

Most fortunately it has proved possible to secure for the exposition of "Mountain Highway Location" an exceptionally qualified writer, particularly when recognition is given, as it will be, to the fact that the author of Book Two has carried on most of his work on these lines in the national parks. There, at any rate, the values of scenic and aesthetic or artistic considerations affecting location are not left out of the items aggregated as a foundation for the decisions of location questions.

I consider Mr. George E. Goodwin, formerly chief engineer of the U. S. National Park Service, the most competent man of my acquaintance for an exegesis of mountain highway location. I had the pleasure of working with Mr. Goodwin in the park service the better part of three years. I am confident there will be general agreement with me in this matter among the readers of "Mountain Highway Location," especially where they shall have been fortunate enough to see and appreciate the admirable results obtained by Mr. Goodwin and his assistants on the national park roads themselves.

W. W. CROSBY.

CONTENTS

Notes on Mountain Highway Location

CHAPTER I

GENERAL CONSIDERATIONS

NO phase of work in connection with highways, from their inception to the completion of the finished road, is of more importance than that part of the work which determines the location of the route. Almost any man, whether he be an engineer, an altruist, an economist, a financier or any layman, may, with sufficient study and with more or less propriety, say that a road should be built from "A" to "B" and that such a road should be capable of carrying two or three, or more, lines of travel; that the road should have not exceeding such and such grades; and that it should be as direct as possible. But to put these ideas into the best results requires a quality of engineering work second to none.

The common impression prevails that the location of a highway consists merely of some man, whether he be a transitman or of higher grade, quickly running a transit line along almost any route and in almost any way connecting the two points, after which levels are run over the line and, in due course, topographic and other surveys made. Sooner or later a road may be built along this route, at an expense and in a manner which may satisfactorily or unsatisfactorily fill the needs for the present or future travel requirements. Little knowledge is had by the layman of the many difficulties and governing conditions which enter into the considera-

tion of the proper location of a highway; difficulties and considerations are always there whether the highway be in a more or less level and thickly settled community having traffic problems; or whether it be in a less thickly settled section but one which presents a number of topographic and other problems; or whether it be far removed from civilization and in a region beset by endless physical obstacles which must be studied and overcome. The problems and difficulties that have to be solved and surmounted are never twice the same. All of these influencing factors have to be taken into account and carefully studied and evaluated, and these factors, in turn, considered with the requirements of the type and standard of road to be built as opposed to the cost of constructing and maintaining the road, thus forming an equation the correct solution of which represents the feasibility of the road in question.

The difficulty of highway location may, in general, be said to vary directly with the topographical or physiographical difficulties which have to be overcome. This is, of course, not literally true, for there are many location factors in thickly settled communities, such as right-of-way requirements, property values, service and commercial considerations, which may be just as vexatious and require just as much or more study than the overcoming of physical obstacles; but insofar as the surveying itself goes, that is, the actual placing of the best line possible within the prescribed limit of funds through a particular reach of country, the more difficult the country is the more difficult the survey will be. Many engineers who have attained more or less enviable reputations in the location of highways through sections of level, rolling or hilly country, along the routes of usual road travel, are lamentable failures when they undertake highway location in difficult mountain regions. There is too prevalent an opinion among engineers that all that is necessary to be a good location engineer is to simply follow out some prescribed limits of gradient and curvature and method of doing such work

regardless of the nature of the country and the requirements of the road; and further, that when they have acquired a fair knowledge of some particular method and kind of location, whether it has been obtained on the flat, desert regions of the Southwest, the level agricultural lands of the Mississippi Valley, or in the low hills of less difficult mountain regions of other parts of the country, then they are fully qualified to undertake any mountain highway location, regardless of how difficult it may be; but this prevailing opinion is erroneous, and there are many roads today which are proof of this fallacy.

The national parks of the United States, set apart as they are to preserve for the use and enjoyment of the people the most rugged and inspiring sections of our mountainous west, present problems in mountain highway location second to none in this country, or probably in the world. The highways located in our national parks cannot, in general, be determined by the standards applied to commercial highways even in mountainous country. The necessity of so locating and constructing national park highways that while they will best develop the parks, permitting the people to visit with a minimum amount of time and effort the principal areas of attraction and at the same time perform this function without marring or detracting from the natural beauty of the area through which they are to be constructed, most of which must be done under extreme physical handicaps, makes this work extremely arduous. Today the ever increasing numbers of automobile travelers seeking new scenic attractions and asking that they be permitted to penetrate further and further into heretofore inaccessible places, brings a demand for a higher type of mountain highway location than heretofore practiced, except by a very limited number of engineers. This type of location requires, in addition to what is commonly considered as the requisite engineering knowledge, an esthetic and an analytical knowledge which will permit the locator to see present and future needs, to en-

visage the finished product, to weigh the disfigurement against the benefit, and to get the best possible results within the limits permitted.

With a recognition of the above requirements, the following considerations and suggestions are offered with a hope that they will prove of benefit to the men of today and tomorrow who will locate and build the roads into the areas occupied by our mighty mountains, heretofore considered impassable for highways, so that the American traveling public and the visitors that come to our country to see our wonderful scenic regions may not only be impressed with the work of the Almighty who formed these master attractions, but that they may also feel that the American engineer, in making it possible for them to see these inspiring and beautiful sections by the construction of roads so fitted to these regions and so built that they do not detract or mar the beauties at hand, has performed distinguished service for mankind.

CHAPTER II

CONTROLLING FACTORS

GOVERNING CONDITIONS

THERE are, in connection with the location of every mountain highway, a number of conditions which govern the type of road, its use, its cost, how it should be constructed, the time necessary for its location and construction, and the present and probable future use or need of the road. These governing conditions all have to be evaluated and given the consideration to which they are entitled.

Among the conditions which have to be given consideration and which control the design and location of the road to a large extent in a mountainous country are the following:

Topographical and Physiographical

In an easy, rolling country and one in which the road will traverse smooth and not too steep slopes, the engineer may have considerable latitude as to the design and probably the actual route and location of the highway. However, where the topography is very abrupt and where most of the natural materials through which the road would have to be constructed would be cliffs, and where there are many canyons and other abrupt topographical irregularities occurring which vitally influence the cost and even the feasibility of construction, the location of the road is often forced into certain definite places. Such conditions require the extensive and thorough study of qualified engineers to secure the best and most economical route. Unfortunately very often such routes have been determined by men who were not engineers or by engineers without sufficient knowledge to know when the ultimate had been attained, and the results are less satisfactory and much more costly.

Climatological

The location and feasibility of roads in the mountains is

often largely governed by climatic conditions. It is, of course, impractical to build an expensive road unless the climate is such that it can be used sufficiently to warrant such an expenditure. In the higher altitudes, especially in our western national parks, the snow conditions have a very important place in connection with road location and construction and the use thereof. In certain sections of our northwestern national parks the snow conditions are such that it would be impractical to build roads or to maintain travel through such regions if the roads were constructed. At the 5,500 or 6,000 foot elevation in Mount Rainier National Park it is not uncommon to find from 10 to 20 feet of snow on the level on the 15th day of June, and snow very often falls each month in the year and nearly always comes on to stay about the latter part of September or first of October. The snow conditions are nearly as bad as Crater Lake National Park, some 600 miles to the south of Mount Rainier, and in each of these parks the snow conditions are worse than in Glacier Park at a 1,000 foot higher elevation and in a latitude 100 miles north of that of Mount Rainier. In Rocky Mountain National Park, situated some 1,000 miles south (in latitude) of Glacier Park, the Fall River Road crosses Trail Ridge at an elevation of approximately 11,800 feet, yet there the snow conditions are not as bad as at the 5,500 foot elevation in Mount Rainier. In general the snow conditions in the Rocky Mountains are not as bad as at the same latitude and some 2,000 to 3,000 feet lower in the Sierra Nevada and Cascade ranges of mountains.

Cloudbursts, such as occur in certain parts of the country, also have to be given important consideration in the location of highways, and it has often been discovered to the sorrow of the engineer and the expense of the public that the relatively small and level valley floor cannot be permanently utilized as the route of a highway through a hilly or mountainous section where heavy torrential rains and cloudbursts are frequent. The nature of the runoff in a region,—that is,

whether it occurs from prolonged hard rains or from the rapid melting of heavy snow fields at higher altitudes,—must likewise be given consideration in the selection of the location. Valley floors in relatively low mountains that have a good brush or timber cover, where streams are fed largely by perennial springs, insuring less extreme high water conditions, may safely be used for a road location. On the other hand, similar configuration without a brush or timber growth on the sides of the hills, and where the soil is of a hard, non-absorbing character having but little surface litter, should be considered with suspicion for a road location, for such an area would be fruitful of sudden floods. The records of the weather bureau and those of other reliable nature should be studied in connection with the road location.

Financial

The financial consideration should be the least considered of the usual governing conditions but, unfortunately, it is often the one condition which governs the location, design, construction, and use of the road. It would be absurd to say the cost of a highway should not be given consideration, as without consideration of cost there would be no real engineering. On the other hand, if a road is needed and the general route is feasible, the construction of a properly designed road over such a route should not be curtailed because of lack of funds. There are, of course, exceptions to this rule. Just as trans-continental railways were first built with extreme curvature and heavy grades through the mountains and of the lightest track materials possible to meet the needs at that time, so oftentimes it is necessary and economical for a state or community to build first a roadway which will meet the requirements that are apt to be placed upon it in the immediate future and to plan on increasing the capacity of this road by bringing it up to higher width standards when the travel demands warrant it and when funds will be more apt to be available for a road of such higher standards. It is, however, essential that where such restricting conditions do

occur that the highway as first located shall be along a route that will permit of its being improved later by widening, ditching, the construction of larger and permanent structures, and by surfacing with suitable materials. Any design and general plan for a highway location and construction should take into account the cost of the work, the financial burden that will be entailed by the taxpayers in meeting its cost, and the benefit that they will derive from its use.

Time

Another condition which is often largely responsible for the location of a road is the factor of time. Unless the engineer is thoroughly conversant with the country in which the road is to be located and has often considered the possibility of its various highway routes, he will instinctively, and perhaps in self protection, if the time allotted him for completing the location is unnecessarily short, follow a route on which he can secure the most data and complete the survey in the shortest time. It has been said that some of the trans-mountain railways have been located through the Rocky Mountains in the passes which they occupy, because of the fact that those passes were the easiest for the locators to get through, in that they were traversed by well worn Indian trails, whereas better routes for the railroads could have been secured through the mountains if the surveyors had been accorded sufficient time to permit their examining the more advantageous passes which were without Indian trails.

Present and Ultimate Needs

Among the most important governing conditions that should enter into the design and location of a highway is the need, both present and future, for such a route. Too many highways are located and built just because some self-ordained booster, or boosting organization, or highway association, thinks that by inciting the expenditure of the taxpayers' money they may pose as public spirited benefactors in that they have promoted the construction of a highway which,

to say the least, is not at the time, and probably will not be for some time to come, needed. Not only should present and future needs for the road effect the design or type of road which is to be built, but they especially effect the location. If there is going to be but light traffic, usually confined to pleasure seekers, it is absurd to construct a highway to meet heavy commercial hauling requirements either as to width, curvature, or gradient. If a 10-foot width of road with sufficient passing places, having up to ten per cent grades, will meet the probable travel demands which will be made upon it for the next 10 or 20 years, then such a road should be built even if it has to be abandoned at the end of that time for a higher type road. It would be cheaper to do this than to construct a high standard road at much greater expense, the cost of which would have to be borne over such unneeded years without commensurate benefits.

Nature of Service

The most important governing factor—next to safety, at least—in connection with the location and design of a highway is that of the service which the road will render, just touched upon in the previous paragraph. Highways which are destined to become thoroughfares in the fullest sense, and which will be traveled by great numbers of rapidly moving vehicles or subjected to a large amount of heavy hauling, must necessarily be located and designed to meet such requirements. For such roads the routes should be so selected, within the limits of reasonable cost, as to permit of roads having easy grades, double or triple travel width, and long, easy curves. Such a road should have every refinement of location and construction possible, for the expense attendant to securing this high standard would be amply justified by the benefit derived. Roads which are destined to be used solely as scenic routes, which will be traveled almost exclusively by pleasure cars—and such is the use to which national park and most mountain roads will nearly always be subjected—should not be built to the standards of heavy

traveled commercial highways. Our scenic roads should be traveled slowly; time is not an important factor to the tourist and the maximum load which can be hauled over such a road should not be given consideration.

Any road, regardless of the use to which it is put, should be so designed and located that it will be reasonably safe for travel. While it is true that on a high-standard road there are more fatalities due to speeding than on a narrower road abounding in curves, nevertheless, there are certain precautions which should be followed to obviate the likelihood of injury to one who drives the road with reasonable care. To this end, highways should not be located in the mountains where the traveler would be subjected to constantly falling rocks; the design should be such that slippery surfaces due to unsuitable surfacing materials would not imperil the traveler; and curves should be as wide and have as much visibility as practicable and should always be provided with warning signs and guard rails or parapets.

Economy of Maintenance

The economics of engineering always require proper consideration of maintenance charges for roads that are to be built, and this is especially true of mountain highways. It is usually better to locate and build a road along a somewhat more expensive route—insofar as first cost goes—than to build it along a route where it can be cheaply constructed but where large sums may have to be spent annually in order to protect and maintain it in suitable travel condition after it is built. Generally the maintenance of a road will be less if the materials which are to be moved in excavation are of a dry, hard and stable character. If soil conditions and drainage are bad on one side of a valley, sometimes the moving of the road to the opposite side will give excavation materials of rock, gravel or hardpan which will obviate the necessity of removing clay or other materials which would probably slide and slough when wet or when frozen. It

is evident, therefore, that care must always be exercised in the location to see that roadways will not be inundated by freshets, washed by side runoff or buried by slides of clay, mud, sand and rocks, and that other probable conditions which would bring about a high maintenance cost are avoided. On summer roads, such as occur in our national parks and in many of our western mountain regions, snow slides from higher elevations on the mountains are often unduly accentuated, for they usually pass over the road without damaging it, unless there are structures that may be injured. With money at six per cent the engineer can afford to spend an added $5,000 per mile if by so doing he can reduce the probable maintenance expense by $300 per annum. Furthermore, of course, in addition to the actual cost of the maintenance, there must always be evaluated the losses due to disruption of travel which occurs when highways become for any reason impassable. In the higher altitudes especial consideration should be given to snow conditions where roads have to be maintained during a part at least of the season when they will ordinarily be covered with snow, and the location should be so made, if possible, that the snow will blow off the roads or will not drift on them badly. For this reason it is desirable that engineers study out the routes of the line during the early spring, when snow drifts are still on the ground, and if possible go over the route of the road during the winter months and see what the snow conditions are.

Next to safety it may be said that economy of maintenance is the most important desired result, at least from an economic point of view. In connection with economy of maintenance there must be given consideration what the surface of the road will be during the first years of its use and what the possible final surface will be; that is, whether it will be a road paved with some so-called "permanent" pavement or semi-permanent pavement, or whether it will be provided with a temporary surfacing of some sort.

RESULTS DESIRED

General

In the location of every mountain highway there must be taken into account the results that are desired to be obtained by its construction and use. Some of the more common results desired have already been touched upon in connection with the governing conditions which, together with the results desired, form the controlling factors in making the location. Like the governing conditions, the results desired have to be evaluated and greater weights given to certain of these considerations, in order that the road may best serve the purpose for which it is designed and fully meet the requirements of the service for which it is intended, and which justify its construction. Among the more common results that are to be secured by the construction of mountain highways are the following:

Scenic

Many of the mountain highways of the western part of the country are primarily built because they will open up some area abounding in scenic attractions. When such is the case, the scenic considerations must of necessity be given precedence in the matter of location—due consideration, of course, being given to safety, construction cost, and maintenance. When roads are to be constructed to open up scenic areas they must be so located that the particular attractions of that area will be made accessible by the road; at the same time, care must be exercised to see that the road does not mar or to any appreciable extent detract from the natural beauty of these scenic areas. The location should be so made that the type of scenery viewed from the road will be varied and so that some particularly striking feature may be viewed from different vantage points, and, ordinarily, the road should be so located that these particular attractions are not constantly viewed by the traveler as he approaches them. Where this occurs, the traveler is apt to be satisfied or palled with

that particular attraction before he sees it from the best view point, and the effect is not as agreeable or the impression as great or lasting as if the traveler has intermittent and different views of not too great duration. Also, the roads should be so located that they will embrace all of the most striking view points for the attractions that may be seen from the particular limits of the location. Where woods and open spaces occur, it is often best to so locate the road that at least a good part of it will be through beautiful, natural timber stands, from which it breaks out into meadows or open spaces offering extensive views. A special effort should be made to bring the road out on to high, commanding view points, from which the surrounding country for long distances may be viewed. Where there are streams having waterfalls, rapids, gorges, or other scenic features, the road should, if possible, come in close to the bank along these attractive reaches of the stream. More pleasing travel results are always obtained if a road follows in the vicinity of a stream than if kept so far away from it that attractiveness of the stream cannot be enjoyed by the traveler. The road should, where practicable, be brought within close view of beautiful dells and spring areas such as frequently occur in our mountain forests. It should not, however, be permitted to bore ruthlessly through these areas so that the natural beauty of these spots will be seriously marred, and it is far better to have the location skirt such areas than to traverse them. In such localities care should be taken to see that fills or cuts are kept to the minimum and that the road fits into the topography as closely as possible. In most of our western mountain areas the scenic value of the road is today, or will be in a short time, the greatest value that it offers. More and more, travelers are each year following the routes of travel which afford the best or most scenic attractions. For this reason it behooves the engineer to give careful consideration to the esthetic and scenic possibilities in order that the road may fully develop the scenic value of the area

through which it passes without detracting from it in any way, knowing that if this is done then the highway will always be a popular, much-traveled route.

Spectacularity

In connection with the possible location of a road from a scenic standpoint, it is oftentimes desired to have the location a spectacular one and in some cases, where mountain roads and highways do not offer especially good scenic attractions, the roads themselves become quite wonderful because of their being located so that they offer certain spectacular effects. In spite of the prevailing opinion that hazard and spectacularity go hand in hand in the matter of highway location, such is not always the case, and often a road which is located and constructed in such a way that its route is spectacular may be just as safe and probably freer from accidents than if along a more conservative and commonly followed location. For instance: if a road should be brought close to the edge of a sheer precipice that would afford an extensive view, it would be spectacular and might be considered dangerous, while if it is kept back 30 or 40 feet along a less steep side slope above the cliff, from which the cliff is not apparent and from which location the view would be very ordinary, it would appear safe. The very fact that in the first case the road is in a spectacular location would cause the motorist to travel with extreme care and there would be less likelihood of accident than if the road was built in the second location, where there would be no apparent appalling abyss into which he might drop if his car left the road. But in the second location the security would be more deceptive, for if the car left the road it would probably go over the cliff also.

The old highway leading from the town of Cody through the gorge of the Shoshone River to the Shoshone Dam in Wyoming (which road forms a part of the eastern approach road to Yellowstone National Park) forms an excellent example of an especially spectacular and in many cases a

hazardous road, for it is very narrow, tortuous, has steep grades and is in many places benched out on the side of almost perpendicular cliffs. In spite of the large travel over it, however, very few accidents have occurred and the impression of this piece of road is probably as lasting in the minds of most travelers as any road they have gone over between the Mississippi Valley and the Pacific Ocean.

Spectacularity in highway location often goes hand in hand with economy, and the engineer who is able to provide a location which will be spectacular, safe, and at the same time more economic of construction and maintenance than a road located in a more ordinary manner, is an engineer with uncommon vision and understanding of mountain highway location.

Spectacularity may be obtained in many ways: sometimes by the benching of the road out of the side of a cliff, or the construction of half tunnels or partial tunnels through a cliff instead of a through tunnel; by the acquirement of elevation; by putting in overhead loop crossings where topography will permit; by taking advantage of topography and putting in hairpin curves so that in making ascents from the valleys to the top of ridges several different elevations of the road are often visible; by bringing the road abruptly out on to high view points; by keeping the highway so located that scenic attractions along it are screened until they burst forth on the traveler as he emerges from the timber or from around some view obstruction. There are, of course, other ways in which a road may be made spectacular, and when such results can be obtained without adding expense and without added hazard, then such spectacular possibilities should be given full consideration in the matter of the location. A striking example of spectacular location is illustrated on the reduced scale road plat, which shows the location of one of the highways in a national park where the road climbs from a valley through to its objective by a series of reverse loops, 13 hairpin curves being used for this

purpose, and from one of the hairpins eleven different levels of the road may be seen below. In the lower section of this road, it will be noticed from the stations and elevations that the road attains a height of 1,920 feet above the starting point in six miles, but that this distance and increased elevation is all obtained in a horizontal distance of about 1¼ miles.

Commercial

Where a mountain highway is built for the purpose of commercial hauling, of course the commercial considerations must be given preference. In such cases, the grades must be kept down to the minimum permitted by the funds and the topography, and the road designed for ample width. Even then some attention should be given to the scenic possibilities, and such scenic attractions as are situated along the road should be made the most of. Quite often it is possible to obtain a fairly scenic highway along a commercial route if the engineer but realizes the value and possibilities of the scenic attractions, and on such a route consideration should be given to keeping the road in green timber, in reasonable proximity to streams, and through the areas which afford the best scenic attractions.

Where, as is seldon the case in the mountains, it is desired to get the shortest possible or the quickest route between two communities, and speed is the prime consideration, then, regardless of any of the above results, the road should be located with as little curvature as possible and with the easiest grades obtainable. Sharp curves should be avoided and usually grade should be sacrificed to secure better alignment. Where roads of this nature are to be built, special attention must be given to the matter of safety, and every reasonable precaution must be taken in the location of the road to this end. Fortunately, roads in mountainous countries are seldom ever planned or constructed with the idea of their being speedways. Motorists who, on the level and paved highways of the more thickly populated sections of the country, travel at from 30 to 60 miles an hour, do not ordinarily, when in the

mountains, exceed a speed of 20 or 25 miles per hour. Wherefore, it may be said that speed is usually the result least desired, and for that reason may be given the least consideration in the matter of the location of mountain highways.

Safety

Of all desired results in connection with the use of a road, the most important is that it shall be reasonably safe to travel, and the locator should, in picking out the general and specific route, keep the matter of safety foremost in mind. In these days of high-speed, high-powered automobiles, no road is safe for a careless driver and, unfortunately, these careless drivers jeopardize the lives and property of the careful driver of the highways. In mountain highways, as in other highways, reasonable safety is best obtained by reasonable alignment, ample width, easy grades, good visibility, satisfactory surface conditions, freedom from the likelihood of falling rocks and timber, freedom from snow and rock slides from the mountain sides above, and by sufficient road side protection in the form of parapets, guard rails, etc., with proper warnings for changes in directions or grades or unusual travel conditions. All of these and any unusual conditions must be taken into account by the engineer in securing a location which will produce a road that will be reasonably safe for the average motorist.

Low First Cost

Unfortunately for the road, low first cost of construction is often the result demanded, and too many highways are constructed in the mountains where the funds are so limited as to prevent their being built along a correct location.

Where the funds available for the location and construction of a road are insufficient to build the standard of road desired on the best location for that road, it is far better that the construction funds be curtailed and that ample funds be made available for the correct location of the road, and that

on such correct location the road be constructed to such standards as the remaining funds will permit, with the expectation that it will be improved to higher standards, and that the work first done will form a part of the finished road. Otherwise, if the location is quickly or incorrectly made, or made in such a manner that the standards of road which will undoubtedly be required later cannot be constructed thereon, then not only will the previous location be lost, but probably a good part of the road originally constructed along this location will have to be abandoned when the higher type road is built.

Too often estimates of the cost of a road along a general route between two points are made by people who are not capable of estimating the cost of the type of road it is desired to build. Often, too, engineers are requested to make an estimate of the minimum cost of a road of some low standard; then, later on, the authorities in power conclude that a road of higher standard should be built along the same route, and the engineer who made the original location and estimate is unjustly blamed because his original estimate was not sufficient to cover the cost of the higher standard road.

One of our large wholesale hardware concerns has as its slogan "Quality is remembered long after price is forgotten," and in the location of highways the engineer might well adopt this slogan. He should always remember that any highway location should be the best obtainable within any reasonable limits prescribed, and that the cost of the location is soon forgotten, but defects in location are always remembered and stand as monumental errors. He should not overlook the fact that whoever may be at fault because of these errors, he will undoubtedly be blamed if the results are evidently unsatisfactory.

Low first cost is secured through locating the road where the clearing and drainage expense will be the minimum, where the quantities moved in the construction of the road will be the least possible and where the character of the materials

encountered in excavation is such that they can be cheaply and rapidly handled, and especially where bridges and other expensive structures can be avoided or kept down to the very minimum. On steep side hills where the topography is irregular, introduction of considerable easy curvature will often reduce the expense of the line materially over what it would be if long tangents were used. Again, flexibility of gradient or a rolling gradient will often permit of a material reduction in quantities without sacrifice of general standards or usefulness of the road. Roads located principally in loose, earthy materials can ordinarily be constructed at from half to one-third the cost of those so located that they are constructed largely from loose or solid rock.

CHAPTER III

KINDS OF SURVEYS

THERE are, in general, four distinct steps or phases of field survey that occur between the inception and completion of any highway project. These steps are usually spoken of as reconnaissance surveys, preliminary surveys, final surveys and construction surveys. The first three fall wholly within the broad term, "location survey," and the fourth is so closely allied to the location that it is often difficult to tell where location surveys stop and construction surveys start. Very frequently construction developments make it desirable to relocate, slightly, certain short sections of the road. For this reason construction surveys will be very briefly taken up in this chapter.

How the various surveys can best be made is, of course, determined by many affecting and governing conditions, as has heretofore been brought out in connection with the general considerations of mountain highway location, and just as in the broader generic sense, so in the matter of surveys, time, funds, topography and climatological conditions must govern, in a measure at least, in all of these surveys. Furthermore, too often the method used in making the surveys is the same as that heretofore followed, under entirely dissimilar conditions, by the man that is in charge of the party, whereas had some other method been used it would have given more complete, accurate, timely and less expensive data. Of course, no location engineer can have had previous experience exactly like the location at hand. No two mountain highway location conditions can be identical. If, however, the locator has a broad experience in similar location he can, if he is a real mountain highway locator, determine, in general, as soon as he has gone over the route and has be-

come acquainted with the governing conditions, in what way the work can be best handled and about where the best location for a certain route will lie. These statements are more applicable to the reconnaissance and to the preliminary surveys than to the final location and construction surveys, for when the preliminary surveys are correctly completed and the data evaluated there is only left for the final location the smoothing out of the line, the balancing of the quantities, etc., and for the construction survey, the staking of the work.

Of the errors made in mountain highway location, by far the greater number occur in, or are traceable to, the reconnaissance or preliminary surveys. They are usually due to inexperienced or unqualified engineers. Errors are sometimes made by qualified engineers but they are generally the result of insufficient funds, or time, for a thorough examination; but are sometimes due to errors in evaluation of difficulties of construction, or use, or to overlooking some potential or actual difficulty or menace not easily apparent at the time of the examination. The errors that the unqualified locator may make are numberless, but some of the most common and which should be guarded against, briefly stated, are: lack of study of all practical line locations and possibly overlooking the best; snap judgment as to which line would be most cheaply built without preliminary cost estimate on the various lines to justify such decision; failure to secure sufficient data as to the nature and quantities and cost of work involved on the various routes to permit of a correct comparison of costs; oversight of actual or potential conditions that effect the maintenance and use, if not the construction, of the road, as lack of stability of materials, subsurface waters, also the possiblity of floods, cloud burst torrents, snow slides, winter ice, etc.; insufficient consideration of usability and purpose of the various routes relative to using the road at all seasons of the year and for the various kinds of transport service desired, together with the safety of travel thereover, the cost of keeping the road open to travel, the expense of repairs and maintenance, the scenic or other recreational advantages, and its connections to other roads built or to be built;

and a disregard of the esthetic considerations, that is, the appearance of the road when completed or its injury of the wayside beauty, including flora, shrubs, trees, cliffs and objects of interest.

As most of the errors of the nature cited, or similar ones, occur in the reconnaissance or preliminary surveys, it is highly important that the man in actual charge of and responsible for the field work of such surveys be an able and honest engineer, fully qualified by experience for the work in hand. (Contrary to a more or less prevalent opinion, a real reconnaissance or preliminary survey is work requiring a high class of engineering knowledge. It consists of more than some poorly paid, unqualified engineering assistant examining or running a couple of lines and choosing which appears the most favorable of the two for the final location surveys.) Furthermore, it is highly necessary that the locator be of an open, unbiased mind and not prejudiced for or against some one location to the disadvantage of others, and that all data relative to the routes to be considered be secured and presented on the same basis.

The decision as to the adoption of a road route is usually based on the data determined from the preliminary surveys as presented by the engineer. For this reason the preliminary survey is the most important of the different surveys, and it is imperative that it be so made as to develop true conditions and that the data obtained be prepared and presented by an engineer that is ethical, honest, fearless, and qualified by experience. Therefore, this chapter takes up more fully the method to be used in the preliminary surveys than any of the other steps of mountain highway location. Further, appended as Chapter VIII are extracts from detailed instructions which have been prepared for the guidance of field engineering assistants in charge of mountain highway location work.

Reconnaissance Surveys

The methods of making a mountain highway reconnais-

sance are so varied even for the same general kind of topography, and so many different kinds of reconnaissance survey methods have been described by other writers, that we shall but generally consider this step of the location survey. In every case, before preliminary survey parties are put in the field, the engineer in charge of the location should secure in the most practical and timely manner a very complete general idea of the topographical and geological features along all probable routes. He should also secure such reliable information as possible regarding all climatological conditions, stream flow, rain and snow falls, etc., also the scenic possibilities, traffic conditions, etc., and all affecting considerations both for and against the adoption of a route. How such information can best be secured the engineer must decide, but in all cases he should never take second-hand information if it is possible to secure the information himself. Furthermore, no man can properly evaluate the mountain road routes unless he studies such routes himself on foot. Too many mountain roads have been built along general routes that seem best as viewed on a small scale topographical map, or on sketch maps that are compiled from defective sketches of topographical features taken from township survey plats. U. S. Geological Survey topographical maps will be found of great value in preliminary studies, and they are surprisingly accurate in general features. They are not made, however, for the purpose of selecting highway routes, and the very nearness of their accuracy may make them dangerous in the hands of the inexperienced locator.

For equipment, an aneroid barometer reading to 50 feet or less, a compass, clynometer, odometer, and a camera are needed. Engineers with acute powers of observation are always indispensable in the reconnaissance of a line. Today general conditions can be rapidly determined by viewing the area from an aeroplane, or by complete sets of topographical pictures taken from one. For this use there are cameras made with which the topographical configuration of the underlying

country can be accurately shown. The pioneers in this type of mapping are Brock & Weymouth.

A study on foot of several routes by an experienced mountain locator will ordinarily give him a very close relative valuation of all the routes under consideration that have been examined, and he will then usually have sufficient knowledge to eliminate all except the routes that seem most desirable, thus accurately narrowing down the choice to 3 or 4 at most, and often to two routes. Even by the experienced locator a revised relative valuation of a route may be had on a second trip over it. For this reason, before preliminary surveys are started, the locator should check up each of the remaining routes by a further examination and make hasty cost estimates of each mile of each route. Money and time properly expended on reconnaissance survey saves greater expenditure of time and funds in the preliminary surveys.

Reconnaissance trips on difficult mountain location are nearly always attended by much physical effort, sometimes with suffering, and often are fraught with dangers. Unless, therefore, an engineer is hardy and experienced in mountain location and possessed of woods sense, he is not fitted for this type of work. In difficult country, even hardy engineers, experienced in mountain work, should be accompanied by a companion that is a good woodsman, and on long, hard trips should be provided with a hand ax for blazing trees, a rope, a small supply of food, matches, and unless water is plentiful, a canteen of water in addition to the engineering equipment above stated.

When the routes have been narrowed down to three or four, or less, over which preliminary surveys are to be made, a detailed reconnaissance line should be run out (by means of a clynometer) to limit, and in many cases to establish the gradient to be followed. Surprisingly accurate gradients can be established by careful use of a clynometer. Trees along the clynometer line should be blazed lightly at intervisible points, or rock cairns set up in the open country, or the line

marked in some way so it can be readily followed by the chief-of-party in charge of the preliminary survey. These clynometer lines, if they are accurate, will permit much more rapid progress to be made by the transit party on the preliminary survey.

Preliminary Surveys

As already stated, the determination of the final location is based on the data obtained from the preliminary surveys, and therefore, the preliminary location should be, and is, the most important step in the location of highways, especially of mountain highways, for in mountainous country relatively accurate data must be obtained from the preliminary lines. Frequently in mountain location by merely moving the centre line one foot horizontally the excavation quantities will be varied by 100 cubic yards or more of rock per station. Often by varying the grades within the maximum limit very heavy rock work can be avoided, which would be encountered if a uniform gradient were followed. Generally the introduction of permissible curvature, correctly positioned, will materially reduce quantities, while unjustified length of tangent increases the quantities. These are but some of the more common ways in which the quantity data of the survey work may be influenced. Further, of course, the quantities are influenced by the way the gradient is laid and oftentimes the class of materials is also affected. Also the distribution and classification of excavation materials is influenced by other conditions, including the judgment of the engineer. Then comes in the accuracy of estimating the cost of doing certain classes of work in certain places as against the same class of work under different conditions at other places. As all of these and many other influencing factors determine the engineer's estimate of cost (accurate or inaccurate) of one route as opposed to another (and cost is too frequently the deciding factor or determines the feasibility of the project) it is highly important that the preliminary location be cor-

rectly made, the quantities and classification closely determined, and the estimates of cost computed on the correct assumptions. Above all, it is important that the locator and estimator be honest with themselves, the project, and the public.

It will also be apparent that the preliminary survey should be much more accurately made and the assumptions used more nearly correct than is possible with the method usually followed by many of the men now engaged in this work. The desired results are possible of attainment only by placing the work in the hands of fully qualified locators; and they cannot be secured if the preliminary line is run and the cost estimated by men without sufficient experience to know how these results can be best obtained.

While there are, of course, many methods of making a preliminary location survey in an open, not too abrupt country, there have been only three practical methods thus far devised for making such surveys in timbered mountain areas. Two of these will be described briefly and the third somewhat more fully.

The method of making a preliminary mountain highway location most commonly followed by American engineers today is to run a transit traverse line, approximating the route of the reconnaissance line, if there be one; if not, then more or less within established gradient limitations; stakes being set every station, sometimes oftener; intersections being flagged and recorded in the notebook with the traverse stationing. Little regard is given to the traverse line closely following the probable position of the final location, although it is usually kept somewhere in the immediate neighborhood and the course, in general, within the limits of gradient. Along this staked traverse line, at station points and at such other places as seem necessary, the ground elevation is determined by the level party. A topography party follows, determining, with a clynometer and rod, and recording the ground slope, at either side of the center line, at each sta-

tion point or other place needed; or else determining the approximate side slopes by securing the approximate elevations and distances out each side of the line with a hand level, rod and tape; or in other places actually cross-sectioning each side of the line for a certain distance, dependent on side slope, etc. This information is taken to the office and a plat is made of the traverse line; on this as a base the side elevations are recorded, and the topography platted, or rather sketched in, making a crude topographical map, upon which the imaginary final location line is projected, curves being selected which seem to best fit the ground, and these connected up by the necessary lengths of tangent. The stationing is scaled out as shown on the projected line. From this assumed centre line, a profile is then taken off and platted, the ground elevation being secured from the projected centre line crossings with the sketched contours, or by centre-line elevations interpolated between such contours. On this projected or assumed profile a gradient is then laid, which seems to give the best conditions; and, with the cuts and fills scaled from this assumed profile and assumed gradient, cross section centre cuts or fills are secured; the base of the road prism drawn in, the ground surface of the sections being secured from the sketched topography, or interpolated, or in some cases the actual cross-sections that were taken on this traverse line are adapted approximately to the projected line. From these synthetically constructed cross-sections the quantities of excavation and fill and overhaul are then computed. Consideration is, of course, given to the class of materials known or assumed to be in the excavation to be encountered. Structure types and dimensions are also based on the field data secured or constructed from the sketched topography. The clearing and grubbing, if any, is determined from this plat, and the other kinds of work taken into account, after which the estimate is prepared for that particular line. This method is patterned after and is an abbreviation of the old railway combination preliminary and semi-final survey, in

which the semi-final survey was actually run out along the projected line or adjusted so that it would fit the ground, after which topography was again taken and the estimate quantities then determined. In railway location, the semi-final survey and estimate being made quite carefully and logically, the procedure gave excellent estimate results, which results—while, of course, costly in the matter of surveys—gave a very economical location for the construction work itself.

It will be readily recognized that with the many assumptions and approximations used in the highway methods of making preliminary surveys above described, the results secured at best cannot be depended upon to be even approximately accurate; and unless the topography is very accurately taken, which is seldom the case because of the great expense of so doing the work in a rough country, the data secured is not worth the cost. Nothing but the law of averages brings the quantity estimates ordinarily obtained by this method within a reasonable percentage of the correct quantities, and the only justification for preliminary location surveys being made by this method in a rough country is that it is about the only method that most engineers understand. In view of the cost of this method of making preliminary surveys, and the unreliable results so often obtained, it should be abandoned in mountain work unless the importance of the work warrants the expense of following up this synthetic survey by a semi-final location that is actually run out and the topography accurately taken therefrom upon which the quantity sections and estimates may be based.

A less common method of making preliminary surveys, but in general a more accurate one, for about the same expense, than the method just described, is as follows: Establish a stake line on the gradient contour, setting the stakes every 100 feet on tangents, or oftener on curves, locating these stakes by chained cord distances, and with an engineer's level, carefully run gradient line. Run a chained transit traverse line in such a manner that it will closely follow the contour stakes. Locate by exact sta-

tioning on this traverse line and by measured offsets therefrom the location of each of the contour stakes. With this information, plat the traverse line, showing the location of the plat of each contour stake, and then on this plat project, by means of curves and tangents projected to *PI's*, a center line which will most nearly follow, within the limits of curvature allowed or desired, the staked contour line. Scale and indicate on this map the stationing and the *PI*, *PC* and *PT* stationing. Then with this plat, or a blueprint of it, or a set of transit notes written up from it, run out and stake on the ground the line including the *PI's* and curves, making such field adjustments from the notes as are necessary, and on this located line take the actual profile and the actual cross-sections necessary to determine the quantities within allowable limits of variation.

The results obtained from this latter method of making the survey will be worth while and the expense and time probably less than in the first method described. By this method, too, most of the work will be done in the field where actual conditions, rather than the assumed conditions used in the first method, are apparent to guide the engineer. This second method of location has been quite extensively used in canal location where accuracy of quantities is necessary, and it has to a limited extent been used by some highway locating engineers desiring both timely, economical and accurate results. It is believed that this method will soon come into the more general use in highway location, which it merits, for it is apparent to the experienced locator that it eliminates the wasted expense of securing inaccurate topography and much of the inaccurate office work of the first method; that it has no step of work that is not needed to secure accurate results, or which is based on assumption; that the office work is reduced to the minimum for the results obtained; that the data secured will usually be sufficient; and that the expense will be well within the reasonable limits for the accuracy obtained.

The third method follows more closely the second than the first, but differs decidedly from both. It might with some justification be called a method of making a semi-final location from

a reconnaissance line, in that it does not embrace either the original traverse control and topography and office projection method of the first, or the contour location and projection cf the second. It might be likened to that school of dressmaking that works without pattern and builds the finished creation by draping the goods on the figure and fashioning the garment to fit the figure rather than changing the figure to the misfit dress. In other words, Mohammed goes to the mountain. In this third method the line is laid in the field with actual conditions as a guide to and test of correctness, not in the office, where neither such assistance nor the test is possible. However, it is sometimes advisable to supplement this method of preliminary highway location in certain difficult and more or less impassable sections with topographic surveys and a projected location; or under other conditions to adopt the grade contour plat system of the second method. No system can be universally best for all conditions.

When the topography is not so abrupt and broken as to make it impossible for a survey party to follow the line throughout, and for the instrument points that are ordinarily needed to be occupied, the following method of making a mountain highway preliminary location will be found cheap, quick, and fairly accurate. This method perforce requires that the man in charge of the party should be a locating engineer, either by talent or development; that he shall be able to envisage how the finished road will look when applied to the places in view, and that he shall be able to picture in his mind, and then in his mind apply to the ground, curves of different radii and length and have them fit the places in question. This last comes from experience. The first is largely a talent. This method is further based on the condition that an accurate reconnaissance clynometer line has been run and approximately marked on the ground by blazing trees, setting stakes at intervals, etc. Briefly described herein, it is further elaborated on in the detailed instructions to field assistants in Chapter VIII.

In general, the procedure is as follows: The chief of party

will, along the route of the clynometer line, establish approximate *PI's* at such places as changes in alignment seem desirable; and unless he is to be with the party when the transit line is run he will, by means of a Brunton transit or compass, determine the approximate angular change in direction at *PI* points and select the radius of curvature that will fit the ground, within the limits imposed, marking this on the stake, and so on. Ready reference tables of curve functions are prepared (see table in Functions for Curves with 100 Ft. Radius), which will assist him in determining what the curve should be, judging this by the external or subtangent requirements. The transit line is then run in, each curve being figured, the *PC*, *PT* and external stakes set, and on long curves the station, half and quarter-station stakes set. This line is then profiled, at which time the approximate transverse slopes, classification, etc., are determined and noted; after which the profile is then platted; the transverse slope indicated; the gradient laid, taking into account the transverse slope, etc., and the curve data, etc., indicated on the bottom of the profile. (It is usually found convenient to plat the profile on a half width sheet of 10 x 10 cross-section paper, using the top inch for showing transverse slopes, materials, classifications, etc., the next seven inches for the profile platted $1'' = 100'$ horizontally and $1'' = 10'$ vertically, the bottom two inches of the profile being used for showing the alignment, curve data, etc. (see Typical Preliminary Profile). When adjustments of alignment or cut are necessary, they are made by taking the profile (which is of pocket size) in the field and changing the location so that the correct cut or fill or alignment (as near as may be had) is secured. The equation due to the adjustment of line is shown, the profile replatted, after which the cross-sections are taken. In smooth or uniformly transverse sloping country, this is usually done by clynometer readings each side of the line, and in rough country by hand level cross-sections at each side of the line. The structures are located and the detailed structure surveys needed are made; the clearing and grubbing areas determined; the cross-sections that are taken are platted, and other areas are determined by

quantity graphs based on certain base width for certain center cuts and certain transverse and side slopes. (See graph of Side Hill Excavation Areas as typical of such quantity curves.) The classification of excavation and clearing is as accurately noted as possible by stations, and on this data the quantity and cost estimate is based. This method of making preliminary surveys is a development from the necessity for some system that will give a quick, inexpensive, and quite accurate and preliminary estimate of quantities and cost under such limitations and conditions as have existed in our national parks of the West, and which so commonly exist in all mountain sections. For such conditions the results obtained by this method are fully 50 to 100 per cent more for the same expenditure of time and money than is obtainable by the first method; the accuracy in a measure approaches that of the second method, and is, of course, less costly than the second method.

When the first method of making preliminary surveys is used it will be found that the final location will be far different in position and quantities than the projected line, while in either the second or last method it will be found that the final location will adhere to the preliminary and that the quantities will be very close, consideration being given to overbreakage and other indeterminate conditions. The last method cannot be economically used by a poor locator, that is, a man who cannot acquire a so-called "bump of location." Locators of moderate ability can often secure more satisfactory results by this method than by any other method, because by a process of cutting and trying they will usually get, on the second or third try, a curve that will fit. Hard headed, merely mechanical locators should not try this method. In fact, they should not try anything in connection with highway location above the work of running a level.

Final Location

The final location consists of refining and perfecting the preliminary location (where the preliminary location is satisfactory), or making such modifications therein as seem desirable. Usually

any experienced highway location engineer can improve somewhat upon almost any preliminary location, however carefully it has been made. On the other hand, if the final location happens to be made by a different engineer, he may unfairly introduce changes in the final location which are not in any sense an improvement on the preliminary line, especially if he is critically inclined. The engineer who runs out the final location should, before making decided changes in the preliminary line, be sure that such changes are needed or justified. So-called betterments that are made at an unwarranted expense are not justified changes, even though they may improve the alignment, grade or width. In many places one can see existing roads of fair width, alignment and gradient that have been abandoned and paralleled by a road built with slightly better alignment and gradient and width at an expense of $20,000 or more per mile, and this done just to meet some rigid standard. Had $10,000 or even $5,000 per mile been spent in revising the alignment somewhat and in widening the old road, a road for all practical purposes as good as the new road would have been obtained, and $10,000 or $15,000 per mile of the taxpayers' money could have been saved.

There are two usual methods of making the final location for a mountain highway. These will be called the "field method" and the "office method." Very briefly stated, these methods are as follows:

The first or "field method" consists in revising the preliminary line as to grades, curves, stream crossing and similar matter on the ground. The determination of what these changes must be is worked out as the changes are developed. In other words, it might be called a revision of the preliminary line by the introduction of different curves and grades for short or long stretches, as the case may be. In this method the stationing of the preliminary survey is not retained, but a new stationing is carried forward which includes not only the revised line but that part of the preliminary line which is used.

If the preliminary line has been carefully made it will, in general, occupy the same location as the final location; but the

final location with its refinements of alignment and grade will probably cross and recross the preliminary line many times and have curvature of greater radius. The engineer will be guided in this final location by the plat of the preliminary location upon which the gradient contours have been sketched, and by the profile of that line, as this information will indicate very closely where changes are desirable.

The second or "office method" of determining the final location is to draw the center line on the preliminary plat containing the sketched contours. The tangents, points of intersection and curves are shown, and the approximate stationing of the new line is determined and placed on the map while it is in the office. This projected location is then taken into the field and the line, with the necessary modifications, run on the ground. The success of this method depends largely upon the regularity of the country and the accuracy with which the preliminary data are shown. In some cases it is cheaper and quicker than the first method, but if there are frequent errors in the preliminary survey, this method is useless.

In making the final survey the same party and procedure are necessary as outlined for the preliminary survey, except that the *PI, PC,* and *PT* are referenced in (located by reference stakes or to surrounding nearby objects whose distances and directions are accurately located) ; tangents and curves staked throughout their lengths, permanent bench marks (*B.M.*) are established and referenced, and the location line tied in at frequent intervals to the preliminary line and with land-ties where such are obtainable. The final location line should be run with somewhat more care and accuracy than was used in running the preliminary location. Profile readings should be taken at all stations and on all changes in the ground that will require cross-sections, and water courses and other difficulties to be overcome should be accurately located and mapped, after which the line is ready for final design and for the construction surveys.

Construction Surveys

Final location surveys actually merge into the construction

surveys in so many ways that often it is hard to distinguish between final location and construction surveys. In general, it may be said that any survey to establish cross-sections, cut or fill stakes, structural excavation, staking or laying out structures, reestablishing grades or rechecking any structure measurements or similar work constitutes the construction survey. As these notes deal only with the location of highways, construction surveys are not taken up; however, the engineer in making final or preliminary surveys should so stake and record his work that the full advantage of the work can be had by those making the construction surveys. The engineer on both the preliminary and final location will, of course, make such surveys at each structure location as are necessary to enable the designing engineer to design the structure.

CHAPTER IV

STRUCTURAL CONSIDERATIONS

IN connection with any location or design of mountain highways, consideration must be given to the structures that will be required on the road. Often it is advisable to build temporary structures which are later to be replaced, but the estimated cost of the road should always take into account such structure replacements, and both the temporary and the permanent structures to be considered in the estimates should always be adequate to meet the probable service that will be put upon them. In most bridges, and in certain types of so-called permanent highway structures, as in railroad structures, it is usually economical to plan upon their replacement when necessary some fifteen or twenty years later because of changed service conditions, rather than to design for an extreme ultimate service which may never come. In other words: *Provide a permanent structure that will probably be used by traffic to a reasonable extent of its capacity for the first ten years and to the fullest extent of its capacity at the end of twenty years.* The statement that the only permanent part of the highway is its location is true, and in line with this we should, in all kinds of subgrade structures that occur under deep fills, provide, if funds can possibly be had, for rock or concrete structures.

Architectural appearance should be considered in all structures. This phase of engineering is excellently discussed in C. E. Fowler's new book entitled, "The Ideals of Engineering Architecture." Mr. Fowler is a consulting engineer of high standing and fully qualified to write upon this subject.

Laymen or engineers that are without architectural, engineering and economic fitness should not be permitted to decide upon the type or the lines and material of permanent

structures such as bridges, etc. Unfortunately, engineers without architectural and esthetic qualifications have built highway structures engineeringly sound but architecturally unsuited. On the other hand, there are today many highway bridges that are correct in every phase of design and fitness, and in most states and organizations where such bridges are being built if the engineering department is not interfered with by commissioners or officials unqualified to pass on bridges and similar structures, still further improvements in this respect will be forthcoming, for the American highway bridge engineer of today is usually a man of high architectural and engineering attainments. The appearance of any highway can be marred or beautified by the unfitness or fitness of the structures that it contains, and the structures in the minds of many travelers make a more lasting impression than any other part of the work. For this reason, the type and material are usually best left to the determination of the bridge engineer rather than the location engineer. No structure that is architecturally correct and properly suited to its location has ever marred the beauty or detracted from the wonders of nature, but a structure architecturally incorrect, regardless of its materials, always does so.

In the consideration of relative routes, the cost of the structures required for each route will often determine which route will be the less expensive to build, consequently the structures that will be required should be given due consideration and their probable cost be carefully determined by the locating and designing engineer.

Culverts

The most common type of structure in the highway is the subgrade culvert. In mountain highway location where provision must be made for rapid runoff, due to heavy rain storms, the melting snows of spring, and steep slopes and consideration given the long and often relatively steep gradient of the roads and side ditches, and the steep side banks and eroding slopes, the correct type, size and place-

ment of the culverts often determines more than any other feature the unbroken use and maintenance cost of the road. Culverts are usually considered as of two classes: cross drainage culverts, which carry continuous or intermittent runoff under the road; and side drainage culverts that carry under the road the water that collects in the side ditches.

For this reason, it is highly important that the field conditions of each location be looked into by an engineer of long experience in mountain highway work.

Side drainage culverts being smaller structures and usually placed near the surface of the road, do not, of course, require an engineering and economic analysis to the same extent as do the large cross drainage culverts. Side drainage structures should, however, be carefully considered as to location and size as well as to type and length. Cross drainage culverts should be placed in all sags in the road, wherever side runoff can be impounded, and in general on stretches of road having 2% or more gradient they should be about 500 feet apart, or not over 500 feet from the last cross drainage culvert. They should be provided with catchment basins at the upper end and with headwalls of rock or concrete. They should be of ample length to give full travel width and should be so placed that the top will be at least one foot below subgrade and should have as much slope as obtainable. They should discharge on rock or in such manner or place as to prevent back cutting of the road fill. The size of the culverts should be such as to pass the probable maximum runoff under a head 6 inches below the shoulder of the road, and in determining the economic size of the culvert the judgment of an experienced mountain highway engineer is necessary. If funds permit and fills are stabilized, it is well to provide reinforced concrete box culverts, or to use concrete pipe or vitreous pipe; however, under nearly all conditions, except possibly under a permanent pavement, corrugated metal pipe will be found both cheap and satisfactory for barrels of the culverts. On account of cleaning sediment out of

the culverts, it is not practicable to use them of less than 12 inch diameter, and if there is a likelihood of much soil movement in the ditches, culverts that are 18 inches in diameter should be used, even though the runoff does not require this size. Side ditches must be of ample size to carry the side drainage to the culverts and where on steep gradients in earth, they should be paved to prevent washing. Side drainage ditches in mountain roads in snow areas should be not less than one foot deep and have a one foot base and three foot top width.

Where swampy or springy conditions occur under the fills or subgrade, blind drains should be provided for. These blind drains may be of 8″ to 12″ diameter tile or 8″ x 12″ rectangular culvert built of flat rock and buried in 6″ to 12″ of gravel covered with coarse sand. Cedar log blind drains are sometimes used and if continuously wet often last for 20 years or more.

Temporary Bridges

Where funds or conditions will not permit the construction of permanent bridges at the time the highway is built, temporary timber bridges (connected with the road but built sufficiently to one side of the final location to permit the construction of the permanent structure later) may be put in pending the construction of the permanent bridge. If the temporary bridge is built on the final location it should be of such span, or its supports to set, as to permit the construction of the permanent bridge without serious interference with traffic.

The type and class of construction used for a temporary bridge should depend upon the length of time and the service to which it is to be put. Piers are usually rock filled log cribs, or else a log mudsill cap and post bent is used. In mountain highways it frequently may be found advantageous to build wet or dry laid rubble masonry abutments and to emplace thereon rustic log bridges. This kind of a structure while temporary will, if properly built, often last for many

years and architecturally they usually look well on mountain roads.

A careful examination along the stream banks in the vicinity of the structure should be made to determine extreme highwater signs, and ample clearance above this mark must be allowed for clearing floating trees with limbs, roots, etc., otherwise jams may occur which may take out the bridge. Where, as in the northern mountain regions, attention must be given to floating ice and where extreme cold is apt to occur for long periods, consideration must also be given to the streams freezing up from the bottom and the water building the top ice higher by running over the top of the ice and freezing and thus forming a sold ice stream which, due to the expansion of the freezing ice might lift the structure off the abutments or anchorage and thus damage or completely wreck it. Where conditions like this may obtain, extra headroom should be provided.

Large Bridges

The total cost of a large bridge (200 ft. or more in span) is almost always under-estimated by the locating engineer, and he should guard against miniminizing the expense and difficulty attendant to the construction of such structures.

Culverts, Small Bridges and Large Bridges

All phases of the location, construction and design of culverts, small bridges, and large bridges should be studied and decided upon by a bridge engineer fully qualified by experience. Fortunately, in mountain highway work the use of large, expensive bridges can often be avoided by careful study and relocation, and the locating engineer should always determine if such is not possible and desirable before he definitely decides upon the location of a road requiring large bridges. In this connection it is recommended that the reader refer to "Economics of Highway Bridge Types," by C. B. McCullough. Mr. McCullough's thorough going treatment of the crossing problem should be investigated before a proposed crossing is adopted.

Walls, Parapets, etc.

Due to the steep transverse slopes often occurring on mountain highways, the use of some type of wall on the lower side of the road to retain the fills is often desirable, both from an esthetic point of view and because of the reduced embankment quantities and lower costs that are thus obtained. Retaining walls are also sometimes desirable along the bank side of the road to restrain the side cut materials from caving into the road. Locating engineers should give full consideration to the use of walls to retain the fills. Sometimes a relatively low wall to catch and hold the toe of the fill will give cheaper results than a wall built up to the grade of the roadway. Estimates for side walls are often made too low because consideration is not given to the necessity of putting the wall down to a rock or solid footing and to the cost of preparing the footing.

On curves and at other hazardous stretches of road it will usually be found advisable to provide some sort of parapet or guard rail. Where in such places fill retaining walls have been built on curves they should be carried up to form a parapet. At these places where parapets are not practical rustic log guard rails should be estimated for, or else where the roadway width is sufficient provision should be made for large boulders or large flat fragments of rock to be set up along the outer edge of the roadway either in contact or set with not exceeding 3 or 4 foot spaces between rocks. The cost of all such structures should be considered by the locating and designing engineer as a proper charge against the estimated cost of the highway.

Other Structures

In addition to the more usual structures that occur on or in connection with highways, such as have just been discussed, there are, of course, other less common structures or features which are sometimes necessary on mountain highways, such as snow sheds, tunnels, river diversion dams, channel changes, berm ditches, under-pass trestles, half benched

roadways, side or hanging trestles, etc. Without attempting to take up the consideration of these different less common structural features, individually, the locating engineer is warned against providing for tunnels where open cuts or different location would avoid their necessity, as they are an expensive and often unsatisfactory luxury. Portal tunnels which so admirably form a part of the Columbia River Highway cannot be economically and successfully used through many rock cliffs, notwithstanding the opinion of many erroneously thinking laymen that they can be. Neither are concrete half causeway sections, similar to the one so well used in Golden Gate in Yellowstone National Park, ordinarily necessary or economical, and any structure either unnecessary or uneconomical is nearly always unsuited and detracts from the highway. The locating engineer should not, however, overlook taking advantage of any unusual type of structure or construction feature if by so doing he may lessen the cost of the route or by such use increase the value of the highway, either scenically or otherwise, providing the expense of the road is not unduly increased thereby. Sometimes in a location on a valley floor the length of the road can be shortened, bridges eliminated and the cost reduced by making a channel change for the stream, and the locator should be sure to take advantage of such opportunities. Estimates for the cost of tunnels and similar special features should always be made by an engineer experienced in this sort of work.

Structural Surveys

The probable work of the location engineer will not extend beyond the structural surveys mentioned in the Preliminary Surveys and Final Surveys, and such additional surveys as may be necessary for unusual structures and to determine the general local conditions and the recommendations as to the general type of the structures, etc., with preliminary estimates as to the costs of the structures; therefore, structural surveys are not taken up here.

CHAPTER V

GENERAL DESIGN STANDARDS

ROAD BED

WHILE no definite standards can be prescribed for all mountain highways or that will apply in every particular to any one highway for all time, we must of necessity assume for each highway or class of highway considered certain standards that will govern in the location and design of the highway and its structures. The standards to be considered in connection with the road bed are alignment, gradient, width, surfacing and nature of traffic. While these standards will be taken up separately hereafter, in the design and location of the highway they have to be considered simultaneously.

Alignment

Within reasonable limits the alignment of the road lies within the power of the locator, but in mountain work these limits are necessarily narrowed, and usually what is considered good alignment in the flatter sections of country cannot be obtained in mountain work, except at prohibitive cost. Frequently it is unobtainable at any cost, and in mountain location the standards of alignment adopted (in an extremely rough, steep, and serrated region) often influence the cost of the road as much as the standards of width within the usual limits of width. Alignment necessarily governs the speed at which the road can be driven by an automobile; therefore, the speed must be assumed in stating the alignment standards. If a road has ample double travel width on banked curves having a fair graveled surface, an automobile well handled can safely make not to exceed 30 miles per hour on a curve of 200 foot radius, 20 miles per hour on a curve of 100 foot radius, and 10 miles per hour on a curve of

50 foot radius, but unless such curves are properly banked and the car is well handled and the surface and weather conditions favorable, such a speed cannot safely be made on curves of these radii. However, on mountain roads most people are careful drivers and generally slow down for sharp curves to twenty miles or less per hour and slower where the curve is suitably signed as dangerous. The matter of visibility must also be considered in connection with speed, for, although it is criminally careless to do so, many thoughtless drivers round curves at quite high speed—on the wrong side of the road. The approximate visibility of two automobiles on the inside of a blind curve having 1:1 side bank slopes and a 200 foot radius is 130 feet; for a 100 foot radius curve, 90 feet; and for a 50 foot radius curve only 60 feet. The sight distance on curves can also be improved by benching back the slopes opposite the *PI*, and in timbered areas by removing brush and thinning trees between the long chord of the curve and the road. Considering the probable safe stopping distance of an automobile, which depends on several conditions, such as speed, surface, brakes, etc., it is wise to assume that blind curves should have twice the radius of open curves if such is obtainable. Some cities require that the brakes of automobiles shall be so set that when traveling at the speeds stated below they shall stop in the distances shown:

Speed of 10 miles per hour	Stop in 9.2 ft.
Speed of 15 miles per hour	Stop in 20.8 ft.
Speed of 20 miles per hour	Stop in 37.0 ft.
Speed of 25 miles per hour	Stop in 58.0 ft.
Speed of 30 miles per hour	Stop in 83.3 ft.
Speed of 35 miles per hour	Stop in 113.0 ft.
Speed of 40 miles per hour	Stop in 148.0 ft.
Speed of 50 miles per hour	Stop in 231.0 ft.

It would seem, therefore, that in mountain highways running through a rough, broken country where heavy curvature must be used, if the roads are driven with reasonable caution there is an ample factor or safety for stopping to

prevent collision even on blind curves with as little as 50 foot radius. On the other hand, the locator should strive in every case to obtain the best alignment possible and should set as his minimum radius of curvature for the lower class roads not less than 50 feet on open curves and 100 feet on blind curves, and for higher class roads the minimum on open curves should be 100 feet and on blind curves 200 feet, and on first class highways these minimum limits should be increased to the extent that reasonable costs will permit. As previously stated, long, easy curves with relatively short tangents ordinarily offer cheaper or more pleasing roads than do long tangents either in alignment or gradient, and the more flexible the alignment within the limits that give the proper support of the road, the more economical will be the cost of its construction.

Gradient

In these days of high speed, the matter of gradient has been made subservient (within reasonable limits) to alignment. There is, however, on all roads used for automobile travel a desire to keep the grade within the limits of high gear travel and never to exceed second gear gradients for a truck that is fully loaded. We find on roads having good gravel surface that for motor equipment in good condition, well handled and properly loaded, that the limit of the first condition is about 6 per cent and for the second condition about 8 per cent. However, on rolling grades and easy alignment, a loaded automobile will probably travel in high gear at least 500 feet on 8 to 10 per cent gradients. While the gradient should be the easiest possible consistent with obtaining the elevation desired, it would seem that for medium class mountain roads the ruling gradient might be as high as 6 per cent, with occasional short bits of tangent having as high as 8 per cent, or possibly, in extreme necessity, 10 per cent grades; that for first class mountain highways the ruling gradient should not exceed 5 per cent and the maximum not exceed 6 per cent, and that these limits should be reduced

where possible to do so without sacrificing distance or cost. In both classes of roads, compensation should be made for curvature for curve angles in excess of 20 degrees. This compensation might well be such that the gradient will not exceed 6 per cent on a 300 foot radius curve, 5 per cent on a 200 foot radius curve, 4 per cent on a 100 foot radius and 3 per cent on a 50 foot radius curve, and in even the preliminary location compensation should be allowed for sharp curvature. Vertical curves of suitable radius should be used at all gradient intersections in excess of 2 per cent difference of gradient. The locating engineer should manipulate the gradient, within the limits allowed, so that he will secure the best and most economical location.

Width

As stated, width and alignment affect the cost of the road more than other factors for the same standard of construction. Width for heavy traveled roads is, within reasonable limits, more important than alignment or gradient. Unless a road has sufficient width to permit two lines of travel, it cannot well meet the demands made by 500 automobiles passing in each direction each ten hours. On the other hand, if there will not be over 100 cars in each direction each ten hours, such travel can ordinarily be well handled by a one-way road having intervisible turnouts. Automobiles can safely pass at slow speed on a road having a top travel width of 17 feet, but for cars to pass at reasonable speed the top travel width should be 20 feet. This allows a 16 foot surface with 2 foot shoulders on each side. First class mountain highways should have a 24 foot width from shoulder to shoulder with an 18 foot or 20 foot surface width. The width of these and narrower roads is given on the drawing herein showing suggested standard mountain road sections. In general, the road should be as wide as may be necessary to handle the traffic that it will probably be subjected to during the first ten years, and, if the funds will permit, it should be sufficiently wide to meet the probable travel demands for the

first twenty years. In scenic places where parking will occur, and in rock work where subsequent additional widening would be very expensive, the road should be built to meet such usage.

Surfacing

Although the construction of the surface of the highway or road has no place in this book, at least a study and decision as to what type of surfacing will best meet the requirements of the road should be made prior to its final location, for the type of surfacing and its probable cost per mile will be a factor that must be taken into account by the locating and designing engineer. Very frequently the cost of a road is based upon using local materials found nearby for surfacing, and the estimated cost of the road so favored, as compared with a shorter road on some other route lacking such local surfacing materials, is estimated to be much cheaper because of the small expense of this local surfacing, which is, say, natural gravel. In such a case, if, after the first road is built, instead of using natural gravel it is surfaced with a durable pavement costing twenty to thirty thousand dollars per mile, it will be found that upon the basis of durable surfacing the second or shorter route would have been much cheaper and in many other ways more satisfactory than the road that was built. In addition to the cost of excavation quantities as affected by the length and width of the road, which must be balanced against the cost of surfacing, it must also be considered in connection with the maintenance cost and the cost of structures, etc., for in general a road that is to have a durable surface must be designed for high standards of construction, including a higher type of structures. The type of surfacing also affects in a measure the location, because if a heavily traveled road is to have a thick surface of some expensive type of durable or semi-permanent surfacing, the subsoil and roadbed bearing power might be ample, whereas it would not be for a temporary or thin permanent type of surfacing. Again, in a cold climate where heavy frost action

occurs, the subgrade for a rigid type of pavement must be well drained, whereas for a heavy gravel surface moist, seeping, conditions might be quite favorable.

Nature of Traffic

The gradient, width and surface conditions necessarily influence the economic use of any highway for certain classes of traffic. As has been previously stated, mountain roads built for scenic and recreational use must be designed to best fit that class of travel. This class of use allows time, gradient, and alignment to be sacrificed in the interest of scenery, comfort and safety. Consequently such a road may have much maximum gradient, considerable curvature, but it should have ample width, protecting parapets and guard rails, and it should be located and built in such a way as not to offend the esthetic senses of the traveler and yet to serve the scenic attractions. For light or medium tourist travel, the width should be ample to permit passing anywhere; extra width should be provided at view points and places of attraction to permit temporary parking. Tourist or scenic mountain roads intended to carry medium or heavy travel should be 20 feet or more wide, and view areas, etc., should have a width of 36 feet or more. On the other hand, for roads that are built for through, high speed travel, both passenger and freight, the alignment should be the best obtainable and should have no curvature of less than 300 foot radius, and have even more radius than this where obtainable. The gradient should not exceed 6 per cent. The travel width should be 20 feet or more. Care should be taken by those that prescribe the type of roads, and by the engineer that locates them, to see that the type and location are such as will best meet the use to which they will be put. Therefore, if the officials that prescribe the type of road are not traffic experts and engineers of highway transport experience, it is important that they call in as advisors men qualified to analyze present and probable future traffic conditions.

In spite of laws and reason, automobiles are driven by

some people at excessive rates of speed under all conditions and on all kinds of roads. Fortunately, mountain highways usually appear sufficiently hazardous to cause even most of these people to drive them at a reasonable rate of speed. Safe driving on mountain roads can be had only when a car travels at such a rate of speed that it can be stopped well within sight distance. Mountain roads should be located and designed for sane drivers only. To try to bring them to the standards of alignment and gradient of valley and prairie roads would be but to increase the number of accidents, for the speed of all travel would be increased. Therefore, in the location and design of mountain roads, the road must be made wide enough, the curvature reasonable, parapets and guard rails and good surface provided, to the end of maximum safety at the minimum of expense. It will be seen, therefore, that while the design of mountain roads must be such that they will meet the traffic requirements to a reasonable extent, they should not in the protection of human life be so located and designed as to encourage, or even permit, their being driven at the high rates of speed possible or even safe on the level, long tangent roads of the flat sections of country.

STRUCTURES

General

With structures, as with the road bed, it is necessary to assume for the purpose of design the nature of the travel to which the particular road is to be subjected, and no general standards can be laid down that will best meet the standards of design for all structures, both temporary and permanent.

Temporary Structures

Assuming that some of the structures to be first built in a mountain road will be of a temporary nature, it is necessary to determine about how long each structure will last, its rate of strength depreciation, and to design it with a factor of safety sufficient to enable it to safely function until it will

be replaced with a permanent structure. The dead load stresses for structures carrying or restraining fills will depend upon the nature of the materials, frost action, etc. Wooden structures which are carrying or restraining earth fills alternately wet or dry deteriorate very rapidly. Therefore, large factors of safety must be used in their design. The live loading on heavy traffic highways is seldom used for mountain highways. However, the snow loading in the mountains of the northwest often places much more severe strains on structures than any live loads to which they may be subjected. On most mountain highways, temporary structures such as bridges, etc., which are intended to carry traffic for two years or more, should be designed to carry, with a factor of safety of four, a twenty ton crawling traction mounted power shovel or tractor having a bearing area of 7x9 feet, and the cost of such temporary structures should always be estimated on a basis to meet these conditions. Where snow loading is excessive, and especially where the structure will support large areas of frozen snow, even heavier structures should be designed. Removing the bark from log stringers will ordinarily double the useful life of such members.

Permanent Structures

Permanent structures in mountain highways should, of course, be much more carefully designed than temporary structures. In general they should, as has been indicated under "Structural Considerations," be of as high standards as obtainable, including materials, finish, etc. The loading factor should be ample and the factor of safety not less than four, consideration being given to impact, and in northern high altitudes especial consideration must be given to frost stresses due to wet earth fills freezing, as well as to temperature stresses and ice and snow loads. The loading and load distribution for reinforced concrete structures adopted by the American Society of Civil Engineers might well be used by the designing engineer. The type of permanent structure best fitted should be determined by the designing or bridge

engineer and must be of good lines and harmonizing appearance. For stone or stone-faced structures, rubble or rough random ashlar masonry should be used, except where in certain cases cobblestone faces are desired. Structural steel bridges should seldom be used except for the longer span structures and these should be designed with due regard to appearance. In spans up to 150, or even up to 200 feet, where rock foundations are available and the head room is ample, concrete arch bridges are to be preferred, and these bridges should be built to artistic standards. For spans of from 300 to 500 feet, suspension bridges may be used more advantageously than structural steel bridges, and for larger spans than these they are always preferable, not only because of their cheaper cost, but because of their better appearance. Short span stone arches may be used under certain favorable conditions, but because of the cost of this type of stone structures and their unsatisfactory appearance, unless built on architectural lines, they are seldom as satisfactory or as fitting as concrete bridges.

Architecture

The suitability of permanent structures from an economical and structural consideration should be decided by the bridge or designing engineer, but unless he is also qualified to consider its appearance from an architectural point of view (and, fortunately, many bridge and designing engineers are so qualified) the design should also be passed upon by an architect fully qualified to do so. In mountain highways, as in other highways, we have come to require that our permanent road structures shall be both engineeringly sound and architecturally correct, and fitted in every way to grace the locality in which they are located and to add to rather than detract from the appearance of the highway.

Materials

The materials used in the structures should not only be suited structurally for the use to which they are placed, but they should also be such as to harmonize with their environ-

ment. Sawn timber structures never look as well in a virgin forest as do rustic log or pole structures. Likewise, fine cut ashlar would not harmonize with a rugged rock surrounding as would a random or rubble stone structure that has weathered stone facing. Therefore, natural materials should be used for exteriors where such meets the needs of the structure and permits of it having lines architecturally correct. Reinforced concrete bridges and similar structures usually appear, because of their light and graceful yet simple and dignified lines, and their soft tonal coloring, to harmonize with, and fit into, any landscape, providing the color of the concrete is such that it is not glaring and inconsistent with the surrounding natural color scheme. Where necessary, harmonizing color effects can be secured in concrete structures by adding a small amount of some coloring pigment to the ingredients that are to form the surface portions of the structure.

CHAPTER VI

ESTIMATES

AS previously stated, costs affect location decisions, hence cost estimates must be probable final costs predetermined as fairly as possible.

The quantities, costs and other factors entering into estimates of costs for highway construction must necessarily be considered for each particular route, and in mountain highways the estimates of costs vary even more than for other classes of roads. For these reasons it is not practical to offer more than a few suggestions as to this phase of mountain highway location and design.

Quantities

The quantities and classifications of the various kinds of work and materials entering into the construction of the road must be as closely determined as practicable by the most economical and accurate methods, otherwise the making of the estimate will be expensive, the estimates of cost will not be correct within the limits allowed for this class of work, and regardless of the correctness as to the unit cost used in preparing the estimates, the costs will be in error.

Preliminary quantities for estimates are usually arrived at as set forth in the chapter on preliminary location surveys. Ordinarily, excavation quantities should be correct as to total amounts within less than 5 per cent, and classification totals within 15 per cent. Clearing, grubbing, structural excavation, culverts, walls, etc., should be closely estimated and all carefully listed in a logical manner so that they can be readily checked. It is always well to make estimates for any uncertain conditions amply large, and classifications of rock, etc., should be quite liberal, otherwise the estimate may be inadequate. Excavation of mixed classes of materials should never be estimated as unclassified or contract bid prices requested on such a basis, as the first does not give an intelli-

gent estimate and the second throws the risk of the classification upon the contractor, and he must bid high enough to protect himself against an unknown factor, thus increasing the cost of the work.

Final estimates should, of course, be even more accurately secured and more complete than preliminary estimates. They should be carefully and logically tabulated by stations or short natural sections of road. Final estimates of quantities should be within 2 per cent of correct on most items and where unknown conditions with reference to classification or questionable foundation conditions exist, liberal quantities should be estimated. It is always better to prepare an estimate that is too high than one that is too low, but in the comparison of one route as against another the same basis of estimate must be used on each route. Estimates should always be complete and contain items for each item of work, including engineering. The preparation of the estimate shows to the experienced road man, better than anything else, the thoroughness of the engineer's knowledge of the road.

Affecting Conditions

The unit or lump sum costs that will be used in the preparation of the estimate must, of course, depend upon many conditions, such as remoteness, seasonal work, climatological difficulties, labor conditions, how the work can be done and the difficulties of the work as well as the time in which it must be completed, all of which make it necessary that the engineer making the estimate be thoroughly qualified by long experience in construction of roads under comparable conditions. The bid price of contractors on certain classes of work under similar conditions is often taken as a criterion of costs for that work, but unless such bid prices are the average of many different contractors' unit prices on similar kinds of road construction, they may be far from correct, for while on a road construction proposal the total of the several contractors bidding may not vary more than 10 or 15 per cent and sometimes less, the unit price will often vary on certain

items as much as 50 per cent or more. The proper unit or lump sum price is that based upon the actual cost of doing comparable work equated to the work in question, and there must be added to the engineer's estimate of such cost, the contractor's financing, camp installation and equipment costs, also his overhead and probable profit if the work is correctly handled. Even costs so determined and probably correct are not necessarily what the contractors will bid the work in at, for often contractors are unable to correctly estimate the cost of the work and sometimes they base their bid upon what they think they can get the work for rather than the cost of doing it. However, the estimate of the experienced engineer, aided by the law of averages, often brings the estimate very close to the actual cost and the bid price for the work.

Variables entering into the cost of comparable work are often overlooked by the estimator. Among the more common of such variables are: the season of the year in which the work is started; the availability of labor or the scarcity of work; the cost of financing work; the difficulty of getting on to the work; the cost of hauling in the supplies and materials and time necessary to secure them; the difficulty of securing men able to do the particular class of work, and the difficulty of performing it in accordance with the specifications.

Other factors entering into the cost of the work are the industrial insurance hazards, labor troubles, the reputation of the engineer that has charge of the construction, the promptness with which estimates are made and paid, the clarity with which the specifications are drawn, the bond required for the contract, the risk and responsibility of the work which the contractor has to assume, as well as the cost of maintaining it during the construction period, and the provision of handling travel over certain parts of the road. All of which must be taken into account by the engineer if his estimate is to be an accurate one.

CHAPTER VII

COSTS OF MAKING SURVEYS, ETC.

THERE are so many variables entering into the cost of making the different classes of surveys that only the probable extremes of costs can be indicated herein. Close estimates of costs can only be made when the actual conditions pertaining to each survey are known.

Preliminary Studies

The cost of preliminary studies for any mountain highway location will be relatively small, but must, of course, vary with the extent of the studies, the availability of the data and the experience of the engineer and others engaged in making such studies, also the difficulties encountered in looking over possible routes. On a basis of percentage, the cost may vary between 1/40 per cent and 1/10 per cent of the cost of the project, or from \$5 to \$20 per mile of the various routes considered.

Reconnaissance Surveys

The cost of the reconnaissance will depend entirely upon the difficulty and remoteness of the country and the experience of the engineer and his assistants in making reconnaissance surveys under such conditions. Ordinarily, in a mountain highway reconnaissance, the cost will vary from as little as 1/40 per cent to 1/10 per cent of the project cost, or from \$5 to \$20 per mile of line investigated. Generally, the reconnaissance mileage will amount to at least four times the mileage of the route selected.

Preliminary Survey Costs

The cost of completing preliminary location surveys will likewise vary with the difficulties encountered, such as timber, roughness of country, climatological conditions, experience of party, size of party and time allowed, as well as with other features. Usually a preliminary survey such as will

give complete field data and made as described in the type of surveys listed under the third method of making surveys in the chapter on "Preliminary Surveys," will cost from 1 to 6 per cent of the cost of the project, or for from $100 to $400 per mile of line actually staked, and the cost of preliminary surveys made by the first or second method would be from 25 to 50 per cent more per mile.

Final Survey Costs

The cost of the final location surveys will depend upon the completeness and accuracy of the preliminary surveys as well as the difficulties and other affecting conditions under which the final surveys have to be made. Usually the total cost of the final location survey will be less than the total cost of the preliminary survey because of the fewer miles of the adopted route, though this may not be the case if the preliminary survey is made as outlined under the first method described for making preliminary surveys. Where the preliminary survey is made as suggested by the second method, the cost of making the final location survey should not exceed over 1 to 3 per cent of the project, and the cost of the final location where the preliminary survey work is done by the third method should not exceed from 2 per cent to 4 per cent of the total cost of the total cost of the project. The total cost of all surveys, up to and including the cost of the finished location drawings and final estimate, should not exceed $900 or $1,000 per mile for difficult country and may be as small as $600 or $700 per mile in easier country.

Construction Survey Costs

The costs of the construction surveys will, for mountain highways, vary with the nature of the work, the speed with which it is accomplished and the kind and size of the construction outfit. These variables are so great that they may make a variation in cost of from 1 to 3 per cent of the cost of the project.

Drawing Costs

The cost of the general drawings, such as the profile and plat of the different preliminary lines and the tracing of the plat and profile of the adopted preliminary line, as well as the finished tracing of the profile and plat of the final line, complete with typical sections, etc., and the plotting of cross-sections, will vary from 1/10 to ½ per cent of the total cost of the project.

The cost of the structural drawings will, where large structures require careful design and elaborate drawings, be somewhat more than the cost of the general drawings and may amount to from ⅓ to ¾ of one per cent of the cost of the project.

Ordinarily, the cost of the engineering up to the construction stage, including the preparation of and issuance of the proposals and specifications, should not exceed 6 per cent of the cost of the project taken as a whole, and under favorable conditions the total of engineering may be as low as 4 per cent of the cost of the project. These costs, with the cost of the construction surveys and the construction engineering supervision and inspection, make the total of all field engineering expense vary from 8 per cent to 12 per cent, or even more, of the total project cost, the actual percentage of the engineering cost to the total cost of the structure being much less for heavy high standard highway construction than for light road work that is done to lower standards.

To the cost above must be added the general engineering administrative and overhead expense, which for large organizations often amounts to as much as 50 per cent of the actual field engineering expense, which often brings the total of all engineering cost to over 15 per cent of the total cost of the project.

CHAPTER VIII

GENERAL INSTRUCTIONS TO ENGINEERING ASSISTANTS REGARDING MOUNTAIN HIGHWAY LOCATION SURVEYS

GENERAL

THE way in which the various parts of road location surveys should be made and the necessary party, equipment, etc., will, of course, depend entirely on a great many affecting conditions. These instructions, however, with regard to field surveys of mountain roads are presumed to be more or less general and to apply to the topographical, timber and geological conditions which will be found in most of our Western national parks and in a mountainous area more or less removed from the roads and where transportation of supplies, etc., can only be by pack outfits.

Examinations and field surveys can usually be divided into preliminary examinations and reconnaissance, detailed preliminary surveys, final surveys, and construction surveys, and they will be taken up in this order herein. How each class of surveys will be conducted must of necessity be governed by the time and funds available and the road standards adopted, as well as by the physical and other existing and controlling conditions.

STUDIES AND PRELIMINARY RECONNAISSANCE

Before field surveys are actually run out or undertaken, the field engineer in charge should make such studies and preliminary examinations as will make him more or less generally familiar with the country in which the road is to be built. He should consult the maps, and especially U. S. topographical maps, if obtainable; travel over as many of the possible road routes, either by foot or horseback, as time and conditions will permit, viewing them with regard to

the difficultness of the work and the other things affecting the cost, such as topographical, geological, timber, and hydrographic conditions, etc., together with the extent to which the road will meet the desired conditions; and above all, its scenic and developing possibilities, all of which are necessary for a preliminary understanding as to where the most favorable road locations are apt to be found. Much country can be hurriedly covered and a pretty good idea as to its topography and elevation secured by the use of an aneroid barometer, a hand level and a clynometer. Some information can often be obtained from local residents. The engineer is, however, especially warned against taking too seriously the opinions and statements of the so-called "old-timers." Their judgment is invariably wrong and the historical information which they give is seven times out of ten incorrect.

PRELIMINARY LOCATION SURVEYS

General

Assuming that a general knowledge of the country has been secured from studies of maps and by personal examination and a more or less general idea as to about what general route should be followed by the road, the engineer is in position to make the actual reconnaissance surveys necessary for a comparison as to feasibility and approximate cost of the different routes.

Reconnaissance Survey

The actual reconnaissance survey is usually made in the field by the engineer in charge. This, in general, consists of a clynometer line which is carried along at the approximate desired grade, decision being made as to probable control points, general changes in direction, stream crossing, and a preliminary decision must be made as to how these different physical obstacles will be overcome. It will often be found advantageous to run two or more clynometer reconnaissance lines, noting the topography and geological conditions and

difficulties of each, as well as the various scenic attractions developed, in order that decision may be made as to the best route. On this reconnaissance line the engineer will decide what appears to be the best way of passing through the various critical or controlled points and decide, in general, where the preliminary location shall be made. Clynometer lines can be run by the engineer alone, but faster work will be done if he is assisted by another man who will help him blaze the line where it is through the woods, or stick stakes or pile rock cairns in open stretches. Trees should be lightly blazed (that is, blazed so they will show a mark about 1 inch to 2 inches in diameter only) and at frequent intervals so that the line can be readily followed. Promiscuous and heavy blazing should never be done along the reconnaissance lines. In a country covered with thick, low brush, small poles can often be stuck up, or rock cairns or ducks built, or sticks stuck in open or grass land. Clynometer lines, if carefully run, are very accurate and, with consideration given to curvature, etc., which will have to be made, it will be found that the preliminary transit line will follow the clynometer line very closely.

Party—Duties and Responsibilities

The party and duties of the men for the preliminary location surveys will depend, of course, on the amount of work to be done, the time and funds available and the nature of the country. Under ordinary conditions the total party would consist of perhaps twelve men, being locating engineer or chief of party, transitman, levelman, special rodman, rodman, two chainmen, stakeman, one or two axemen, a cook and a packer.

The ENGINEER'S duties would be to have general charge of all administrative and field work, to make the preliminary studies, run out the reconnaissance clynometer lines, run the camp, direct all operations on the survey and hire and discharge the men occupying minor positions and make recommendations and reports relative to other employes, report the work and keep a cost record of same.

The TRANSITMAN'S duties will be to run the transit, keep the

notes, check them, plat the line, and do such other work as the engineer in charge may direct, and in the absence of the chief of party or locating engineer he will take charge of the work and act for the engineer in all matters. He will be personally responsible for the use and protection of the transit and its supplemental equipment.

The LEVELMAN will run the level, keep level notes, check them, plat the profile, reference in the line, take topography if directed, and carry out the instructions given by the assistant engineer, and in the absence of the assistant engineer and transitman will be in charge of the survey. He will be personally responsible for the use and protection of the level, etc.

The SPECIAL RODMAN will have no regular duties, but will do such work as is assigned to him from time to time by the assistant engineer, whether that be checking notes, making comparative estimates of costs, or doing field work in a minor capacity. He is usually considered as supernumerary, and should be able to run a hand level, a clynometer, record notes or, in fact, work in almost any capacity except that of transitman and he might well be an understudy to the transitman.

The RODMAN'S duties are to assist the levelman in profiling the line or taking cross-sections. He will be responsible for the use and care of the level rod, and such other tools as are given him.

The HEAD CHAINMAN will be responsible for the use and care of the chain and the range pole used. The rear chainman will be responsible for the metallic tape, plumb bob, and such other tools as are given him. The stakeman will be required to see that ample stakes are on hand, that he is supplied with marking keel, and he will be responsible for the stake sack and stake ax. His duties will be to mark and drive the stakes and do such other work as may be assigned to him. The axeman if only one, will usually act as head flag, in which case he will not only be responsible for the ax, etc., given him, but also for the picket which he uses. His duties, of course, will be to brush out the line, and do such other work as assigned.

None of the men in any of the above listed or unlisted positions will be considered as having any special duties which would exclude them from doing any work which is necessary for the proper progress of the survey, or which they are directed to do by the man in charge of that party or by the engineer in charge.

Equipment

The equipment necessary for preliminary location surveys

will, in addition to the necessary camp and mess equipment, consist of a transit, a level, one or two clynometers, one aneroid barometer, one or two hand levels, two 100-foot chains, two or three metallic tapes, two level rods, two range poles, several axes, usually a paint brush for the painting of trees and certain other miscellaneous camp and line equipment. The equipment will, of course, vary somewhat in accordance with the size of the party and the nature of the work to be undertaken.

Method

The method to follow in preliminary surveys will depend on the results sought and the country through which the survey is to be made, as well as the funds and time available. In general, however, it is assumed that the preliminary location will follow the gradient or reconnaissance lines previously run out by the locating engineer and that the preliminary location will be run out with a transit; staked on the ground; *Pi's* set; certain of the *PI's* referenced in; curve radius determined; curve length determined; *PC's* and *PT's* set; station set at least every 100 feet; the line profiled at each station and oftener as needed to determine the ground breaks; and that the transverse slopes will be determined for the probable construction distances on either side of the line (these slopes will be determined by either a clynometer or hand level); that the timber growth, the clearing and grubbing, etc., will be classified and the areas estimated; that the nature of the materials to be moved in excavation will be determined, and that data necessary for estimating the cost of bridges and other structures will be secured.

Time and Output

The amount of time necessary to make preliminary road location surveys depends, of course, on the difficultness of the country, the size of party and the thoroughness with which the work is done. Generally, with a party as outlined above and topographical and timber conditions such as are found in high mountain country, from one-quarter to one and one-half miles (aver-

aging about one-half mile) of line per day can be staked out and profile and topographical and classification and structure notes secured, the amount, of course, varying in accordance with the difficultness of the country. In thick, high, and large brush and broken country, requiring continuous curvature, progress will be slow. Where *PI's* will average 500 feet or so and little brush cutting is required, one and a half to two miles should easily be obtained by an experienced party.

THE TRANSIT LINE

Party and Equipment

The transit party will generally consist of a transitman, a head and a rear chainman, a stakeman, and in timber work a combination axeman and front flag. Where timber and brush is very heavy, an extra axeman may be necessary, but in such places all of the men except the transitman will carry axes (or brush knives). The head chainman, however, will carry a hatchet or belt ax so it will not interfere with his carrying a picket. The equipment will, of course, be what is necessary to do the work. In addition to the transit, chain, flag, etc., there should be on the job at all times a second chain to be used in case the regular chain is broken.

Controlling Factors

The transit line will either follow the clynometer gradient line or, in the absence of a clynometer line, be run on a gradient line if gradient is the controlling feature. In the mountains, gradient usually, wherever practical or possible, controls and a clynometer line should first be run and the line blazed or otherwise marked as it is selected.

In running the line, its location will in many cases have to be decided by the controlling factors, such as curvature, views, critical elevations, river crossings, etc., and consideration must, of course, be given to all such features, but care should be exercised to see that the line is kept in as good alignment as possible and yet meet the necessary conditions.

Standards and Accuracy

The standards to be observed will vary with the road and the difficultness of the country. Extreme accuracy is not expected and should not be striven for in the preliminary line. Distances within one-tenth of one per cent and angles read to approximately the nearest minute are sufficient. Intermediate stakes should be quickly set without rechecking by the transitman. Tacks should only be put in *PI's* and *POT's*. In so far as possible, consistent with securing the data necessary, output rather than extreme accuracy is to be the determining factor in preliminary location surveys.

Grades, Curvature and Width

The gradient and curvature will vary somewhat for the different roads and will of necessity be governed somewhat by the country. The present standards require that 6 per cent shall be the general maximum controlling grade, that the maximum allowable grade for short stretches shall not exceed 8 per cent on Class II and III roads and 10 per cent on Class IV roads, but that this maximum gradient shall be used only where necessary, and that grades shall be compensated for curvature if the radius is less than 300 feet and the curve angle over 20 degrees. The minimum allowable radius for curvature is 50 feet and this small radius can be used only where necessary on reverse loops occurring on side hills, or where it is absolutely necessary on account of physical difficulties. In general a radius of 200 feet or more should be used if more than 20 degrees of curvature is involved and the topography will permit. See drawing No. 9 for the width of the different classes of mountain roads.

Roads in national parks and other scenic areas are not ordinarily built for commercial use; therefore the standards governing commercial roads do not apply. Long tangents are not wanted and a certain amount of curvature is desirable. While uniform easy gradient is desired, ruling grades may be used (as may be necessary within certain limits) to

fit the line into the country and to reduce the cost of constructing the road.

RUNNING IN THE TRANSIT LINE

Determination of Curvature

There are, of course, different ways of determining what curvature will best fit a definite amount of change in direction and the particular topographical conditions. To facilitate a rapid decision as to this, curve tables have been prepared for use in this service, from which one will be able to determine by inspection the approximate radius of the curve necessary to give either the desired external or desired sub-tangent length. See "Functions for 100 Foot Radius Curves." If there is ample subtangent length on each course available, then the external distance necessary to give proper support to the line will usually be the factor determining the radius. On the other hand, where the subtangent distance back or front is limited, such distance will usually control. Inspection of the prepared tables will enable almost immediate decision being made as to the radius of the curve desired or permitted, and when this is decided then it (length of curve and tangent distance *T*) can be taken out, the external distance secured, and from the accompanying tables the deflection for fraction of station and the chord length from the *PT* determined.

Running in Curves

Short radius curves of short length need not be run in by transit deflections, but the *PC* and the *PT* should be set with the transit. The external should be set, its angular position being determined by the eye (the external stake should be set edgewise to the line). Where even stations occur on the curve they should be put in. Their angular position can usually be determined close enough by the eye but their distance along the curve should be measured. Longer curves in open country should always be run in. This is more quickly done from the *PT*; deflections being read on the stakes which, with chord distances, are taken from

the table of Deflections and Chords for the radii listed of the commonly used short radius curves. For other radii they will have to be figured. The correct position of the *PT* should be checked by curve measurement as well as tangent measurement from the *PI*. Curve stakes on preliminary are usually set at 50-foot intervals, except on very sharp curves, where they should be set every 10 or 25 feet. By occupying the *PT* one set-up is saved over that if the *PC* is occupied. Where the *PT* is to be occupied a pencil mark or "*X*" mark should be placed on the stake as it is set on the tangent line ahead as a centre point for the transit. When the transit first occupies the *PI*, the *PI* ahead should be set and centred. The *PI* ahead can usually, unless the distance is great, be set sufficiently close to the desired position by setting the angle on the plate to read to the nearest degree or tenth of a degree, as this will permit of more readily taking out the curve functions from the table.

Where a long curve occurs in thick brush it will be found cheaper to locate the curve sub-stations by offsets from the tangents. The graphs of Drawing No. 6 will give sufficiently accurate results for preliminary surveys only, or for clearing lines on final surveys.

Cutting for the Line

No more cutting shall be done for the line than is necessary to run it in a fairly cheap and expeditious manner. For a preliminary line this will usually consist of cutting brush and such very small trees as occur on the line and cutting off limbs which may stick out from larger trees. Large trees should not be cut. It is cheaper to offset around them than to cut them. Further as the road may not be built on the preliminary line, we must not leave the forest scarred by the cutting of large trees, neither should trees be blazed more than is necessary in order to properly mark the line. Large blazes should not be made either for bench marks or reference points or for line blazes. Blazes 2 inches in diameter, if they are sufficiently close together (and they should be on nearly every tree which is in close proximity to the line),

are amply large to permit the line to be followed for some three or four years at least.

Staking the Line

On tangents the line should be staked every 100 feet on preliminary, or oftener if necessary, and as stated, at every *PC*, external, and *PT*, and on curves at every 50-foot station, or oftener. Witness stakes should be driven at each *PI* showing stationing. The only hubs to be used are those on *PI's* or *POT's*. which should be tacked. Hubs should usually be 6 inches to 1 foot long, depending on how deep they can be driven, of 1½ inches or more diameter or section, and be driven down flush with the top of the ground, or as near that as possible, with a witness stake so placed that its marking and stationing will be facing the hub and within a foot or such a matter of it. Station stakes should be driven in sufficiently firm so that they will not be knocked out, and should, of course, be set transversely to the line. It is better to have a stake break off in the ground than to have it easily knocked out. Stakes should always be marked so that the stationing will be read as one walks along the line. Care must be exercised to see that they are firmly, accurately and neatly marked. Black keel or lumbermen's crayon should be used for this purpose, as it lasts longer than blue or other color of crayon. The stakes should be marked from the top down with the station number + 00 for even station stakes, and the station number plus the fractional distance for between station stakes, and in the case of *PT's*, *PC's* and *PI's* the station will be preceded with the proper capital letters to indicate the nature of the stake.

Making Stakes

On preliminary surveys it is seldom ever practical to purchase stakes which have been manufactured elsewhere, consequently they will have to be made from the timber at hand. Cedar and redwood make the best stakes. Sugar or white pine stakes are the easiest marked. Fir and spruce make good stakes. Any of these varieties of timber may be used where only that particular

lumber is available. Jack pine is not much good and should not be used unless necessary. Stakes can be made by sawing blocks from dead or down logs which are still sound. Stake blocks should be about 14 to 16 inches long. Stakes should be froed out by the use of a regular froe, a bench ax or hand ax, and should in general be about 1/4 to 1/2 inch thick and from 1 1/2 to 2 inches wide, one end being pointed. One side of the top end of the stake may be smoothed somewhat by passing a sharp bench ax over it as a plane; however, but little time should be used to do this as usually the soft wood stakes can be marked fairly well.

Witnessing the Line

The preliminary line should be witnessed in at frequent intervals so that it can be retraced without too much difficulty or without having to be rerun for long distances. In general, one tangent should be referenced in about every thousand feet, that is, the *PI's* should be witnessed. The end of each tangent should be definitely located with regard to some substantial object, usually trees, which will be outside of the probable right-of-way of the road and usually on the upper side of road. Distances from these trees to the *PI* will be measured fairly accurately, either with cloth tape or chain, along the slope distances. The measuring point being marked on a tree as a triangle and a nail driven into it. Reference points should be as near to right angles as possible and usually at about 45 degrees from the center line of the road, preferably both on the same side of the location. Triangles may be marked with an ax or, better still, by paint, and the station of the *PT* which they are referencing shown on the same tree. Oftentimes this is best done by showing it on a stake and nailing the stake on the tree near the *RP*. These *RP* distances and the approximate location of the tree, together with the description of the trees, should be entered in the transit line note book.

Economic Cuts

The transit line should be so run that the economic cut will be secured in so far as practicable. This will vary for different

road sites and different slopes. On steep slopes the economic cut or necessary cut will, of course, be much more than on the flatter ones. On steep side hills having transverse slope greater than 1¼:1 the road section will ordinarily have to be a full cut section unless side retaining wall is built to restrain the fills. On flat ground the ordinary standard road section is most economically constructed when the grade line lies at the top of the ground or above it. Below 20 degree transverse slopes the centre cut should be from ½ foot to 1½ feet, dependent on road width, cut and fill slopes and other conditions, and from 20 degrees to 40 degrees transverse slopes the cut should be from 2 to 4 or 5 feet, dependent on the width of the road and fill conditions. The theoretical cut will also vary for different classes of materials. All of these have to be taken into account in connection with the location of the preliminary transit line if correct estimates of the necessary quantities are to be secured therefrom. The engineer should remember that rock increases a great deal in fill unless it is a flat laminated slate or lava rock which would slide off a side slope. Soft materials, especially those of the clay nature, which would slough when wet, must be taken into account as their value in fill will usually be small.

Platting the Line

It is usually desirable to have a brown paper plat made of the line. In general, this can be done best on a scale of 1 inch to a 100 foot station, although this scale may have to be varied to meet certain other requirements. Too much pains should not be taken in platting the line as it is, in general, platted merely to show the general curvature with regard to its immediate self.

There are various methods of platting the line. Preliminary location center lines should never be platted by any extremely expensive, accurate or slow method. Latitude and departures should never be used unless a definite closure is needed. If a protractor is used it should not be laid closer than the nearest degree. Distances should be fairly accurately measured between *PI's*. Curves should be drawn in after the tangents have been platted. In order to prevent accumulations of errors, etc., the

computed course should be used and the angles measured from a definitely established azimuth or base course line which is put on the paper. If suitable protractors are not at hand, courses can be rapidly projected by the tangent method. This last method consists of erecting an upright on the azimuth line at 100 units from the initial point of measurement and then measuring the natural tangent off on the vertical line for the angles between the azimuth line for the point in question, and then transferring this azimuth direction by means of triangles to the last *PI* platted, the new tangent length being measured on this line and the method repeated. The most rapid and accurate results are obtained, however, by using a large size half-circular protractor and transferring the angle direction to the *PI* by a rolling parallel ruler originally positioned against the edge parallel to the 0-180° axis.

Transit Line Notes

The value of the transitman is as clearly demonstrated by the way he keeps his notes as in any other one thing that he does. It is about as essential that notes be fully and accurately kept as it is that the line be located on the ground correctly. The transitman should always strive to have his notes both neat and accurate; a hard pencil should be used to record them. The letters and figures should be of small size and legibly made. Sketches which are made should be sufficiently comprehensive to be understood and labeled as necessary to this end. The first page for a certain piece of work is used for giving a brief description and the name of the line to be run. Each day's work should be dated and the party and its duties stated at the top of the page and the customary notes recorded as the work is done. The transitman in recording his notes should remember that the man in the office, who has never seen the work, or the man who follows him in retracing the line, does not know what he is thinking when he records the notes and has to be governed by the notes themselves as recorded rather than by what the transitman knew about the situation at that time but did not indicate in the note book.

PROFILE OF LINE

Party and Instruments

The level party will ordinarily consist of a levelman and rodman and the necessary equipment, such as level, rod, ax, keel, metallic tape, etc., so that bench marks can be established, reference points measured in, detailed profiles made for structure locations, etc.

Work to Be Done

In a preliminary location survey, profiling the line usually consists of determining the ground elevations at the foot of the station stakes and at such intermediate points as may be necessary in order to indicate an approximately true profile condition. Ordinarily intermediate points between stations can be located sufficiently accurately by pacing the distance over from the nearest station. The rodman should always call the station to the levelman whether the reading is taken at even station or at a substation, and the levelman should call the stationing back so that there can be no error. In addition to this profile, a line of differential levels is carried along for the establishment of benches for use in connection with future road surveys. Initial elevations should, where possible, be taken from bench marks of known elevation. Where this is not possible, then an elevation may be assumed. For a general road survey, however, a reasonable elevation should be assumed. This can usually be arrived at within 100 feet by a barometer reading or by reference to some topographical map. The differential levels which are carried from this initial bench mark should be accurate within a reasonable degree. The rod should be carefully read to the nearest hundredth, the level being leveled up before the front and back sights, and if there is reason to expect it is out of adjustment the fore sight and back sight should be of equal distances. Considerable speed can be made in setting the level up for back sights if a hand level is used to determine the desired height. When going rapidly up hill back sights should be approximately the extreme height of the rod. When going down

hill back sights should be something less than one foot and oftentimes they may be only one-tenth or so, and, of course, fore sights for *TP* should be the opposite rod condition. In level work speed can be obtained without sacrificing accuracy to a greater degree than in any other phase of location surveying.

Platting the Profile

The profile levels should always be kept up close to the transit work and at night should be brought up to the last center line stake established. Every evening the levelman should plat up his profile so that the engineer may make a graphical inspection of the work that has been done during the day. Profiles are always platted on a half width of standard cross-section paper, 10 x 10, at the distorted scale of 1 inch equal 100 feet of line horizontally and 1 inch equal 10 feet vertically. Profile of the line should be contained within the second to seventh inch from the top, so as to provide two inches of room at the bottom for location notes and symbols and one inch at the top for clearing and other symbols (See standard profile, drawing No. 1.) In the field, profiles should always be platted on the standard profile paper, not on tracing profile paper.

Stream Crossings

At stream crossings, either large or small, profile stationing and elevations should be recorded at each side of the stream, at all breaks, at the extreme indicated high water lines, at the low water lines, and at enough places on the bottom of the stream so that the depth of the water can be determined and a profile of the bottom platted; also the approximate slope of the stream should be secured by a transverse profile with bottom readings every 25 or 50 feet for 100 feet or more to the right and left of the line and, of course, the distance recorded to these various points. If known, the name of the stream should be stated. If it is running water and has the appearance of a permanent stream, such should be noted, or if it is only a flood water channel this should be noted.

Bridge and Culvert Locations

Where large bridges or culverts will be required, considerable more information than that stated above will be needed. In such places the levelman should make an approximate sketch of the general layout and indicate the elevations of the different materials and anything else necessary for approximate design data for structure. A sample form is shown for such work in drawing No. 11, which form provides for the sketch and the information necessary in final field notes for the design of the structure. This should be followed to a certain degree in getting the preliminary design notes.

Heavy Rock Work

Where heavy rock work is encountered and the price of the excavation will be two or three or more times higher than the price of earth work, it will be necessary to make a more accurate profile. In these places more frequent readings will be needed, and where there are a large number of boulders scattered on top of the ground, notes as to the number and approximate size of them per station should be made, so that they may be considered in the preliminary estimate.

Notes

The levelman should keep accurate and neat notes. Pencils sufficiently hard should be used so that they will not smut or become illegible. Sketches and preliminary notes should be made, as necessary, on the right hand page. The level book, like the transit book, should have at the beginning of a job a statement as to what the work is. Each day's work should be dated and the party's name stated, the names of streams, if known, should be indicated and all other information should be included which is necessary for a correct understanding of the work by the office engineer or anyone who has not been on the job. Elevations should be extended as the line is profiled, elevations on the ground being recorded to the nearest tenth; *HI* and *B.M.* elevations and differential level rod readings being shown to the nearest hundredth.

Bench Marks

Bench marks should be established at intervals of about one thousand feet, or such a matter, along the line, usually at some place which will be outside the right-of-way of the road as it will probably be built, and at some place where it will be convenient to pick up the elevation. That is, without having to set up two or three times in order to get on to the road grade. Bench marks should be established on something that is of a permanent nature, such as the point of a large rock or the root of a fair sized tree, and they should be assigned a number and a stake with the *B.M.* and elevation placed in close proximity to the rock or nailed on the tree, or in some places a small blaze can be made on the tree and the *B.M.* and elevation to the nearest hundredth shown thereon. If on the root of a tree, a small knob should be chopped and a ten penny spike driven into this so as to identify the exact *B.M.* locaton.

TOPOGRAPHY AND MATERIAL SURVEYS

This work in connection with preliminary location will consist of determining such topographic and material data as is needed to make a correct estimate of quantities and costs to be based on the profile cuts, etc.

Party and Equipment

The party that will be used on topographic and classification surveys will depend on the speed necessary and men available. Ordinarily the level party can take the topography and make the material surveys in addition to keeping up the profile. When, however, this is not practical for any reason, the work can usually be done by one man who will have to estimate his *HI* when taking slopes with a clynometer and have to pace in cross-section data, distances, etc. Where great rapidity is sought a party of four men will do very rapid work. A rodman on each side of the center line will give the *HI* for the slope or rod readings and distances, a third man will record the slopes or rods and distances and material classifications, and the head of the party will decide on what the classifications are, and take the slope readings. The

equipment in this last case will consist of a clynometer, two rods, a cloth tape for taking cross-sections where necessary and a hand level to supplement this equipment. There are, of course, other methods of doing this work and where that which is described does not apply some other method will have to be used.

Time and Output

The time to make these topographical and classification surveys is when the ground is free from snow and it should be made, if possible, as soon as the profile has been run, for if the material survey information is at hand it will often decide questions relative to laying the grade line on the profile. The output of a party will depend on its size and the difficulties of determining slopes and the changes in classification. On ordinary work, one or two men parties should be able to classify from one to two miles per day. A four-man party should be able to classify from two or four miles, or even more, per day.

Transverse Slopes

Topography is usually taken with a clynometer by reading the average ground slope to the right or left of the line for a distance of 20 to 40 or 50 feet as may be needed to cover the road prism, recording the slopes at each side of the center line in angular measurement, these side slopes being determined at every place in which a change of slope occurs. Side slope readings should be taken to the nearest degree or nearest two degrees. Where abrupt changes occur in the transverse section, as at the foot of cliff, or top of a cliff, or in rock where there are any vertical breaks, a combination side slope and cross-section may best show the conditions. Sometimes these special sections can be recorded by means of sketches with dimensions shown on the right hand page of the note book.

Classifications

To determine the cost, the difficultness as well as the nature of the work must be known. The timber stand must be described at each station or at every place where a change occurs. This is

best done by classifying it, which classification for the purpose of estimates may be as follows:

No clearing: Where only grass or a very small brush cover exists, 90 per cent of which brush could be mowed with a brush scythe or the ground plowed by a heavy 4-horse team attached to a suitable road plow.

Scattering trees: Where trees stand by themselves or in groups of two or three and occur not oftener than every 30 to 40 feet along the right of way. The approximate size and spacing of these trees should be shown.

Brush: Where there are few if any trees and where the brush varies from 3 to 6 or 8 feet in height, and which brush would have to be cut and disposed of before the ground could be grubbed.

Light clearing: This will consist of scattered large trees where not over two trees of 2 feet or more in diameter or not more than 25 trees varying from 4 inches to 8 inches in diameter occur in a single station length of right of way.

Medium clearing: Where there are from 2 to 5 large trees 2 feet or more in diameter, and 26 or more trees from 4 to 8 inches in diameter occurring in 100 feet of the right-of-way, or where the ground has been burned over within the past two years and the small trees and brush, etc., killed and only the larger trees remain to be disposed of.

Heavy clearing: Will be allowed in all places where heavy stands of virgin timber occur where there are six or more trees of 2 feet or more, or 10 trees of 1 foot or more in diameter in 100 feet of the right-of-way. Diameter of trees in all cases will be measured at height above the ground level equal to the diameter specified, and right-of-way will be considered on a basis of being 40 feet wide.

Merchantable timber: Where it occurs should be noted. This will generally consist of trees which will square 10 inches except in the case of cedar which will be considered as merchantable in pole size of 4 inches or more top diameter. In all cases of heavy

timber growth grubbing will be required for the road prism between 2 feet below and 5 feet above the grade of the road surface.

Excavation: Class I excavation is dirt, sand, clay, loam and other similar materials, either free from or containing isolated rock of less than ½ cubic yard volume. Class 2 excavation consists of loose rock, shale, hardpan and other materials which have to be gadded or blasted to be loosened when not frozen, and isolated boulders which are ½ yard or more than 1 cubic yard in volume. Class 3 excavation will consist of rock or ledge in place or isolated boulders of more than 1 cubic yard in volume.

In classifying excavation the surface indications cannot alone be considered as sufficient. The steepness of the slope, the materials found under upturned tree roots and in genreal the appearance of the soil in the gullies and washes must be given consideration. A steep slope, that is, one of 30 degrees or more, usually means that hardpan, cement gravel, or loose or solid rock lies within a short distance of the surface. Oftentimes on steep slopes, rock excavation will be encountered in ditch areas, even though not occurring in the upper portion of the road prism.

Location of Materials

Conditions should be noted and recommendations should also be made as to where materials for fills, surfacing, graveling, structure materials, etc., can be secured and where they will be required. Also statements as to where good timber for cribbing or temporary log bridges or for buildings can be secured. Special consideration should be given to the classification of materials in close proximity to bridge sites or other important structures, both as to the material which will be encountered and where the materials can be secured which will be needed in building the structures. Details relative to structure location and materials should be given and sketches provided where necessary to more fully and clearly explain conditions. Use the standard structure sheets for this purpose.

Recommendations

Materials in topographical surveys have a very important

bearing on the estimated cost and method of the proposed work. It is essential that they be complete and correct. It is necessary also that recommendations be made as to how materials can be handled, how the work should be done, how economies can be effected in construction and design, and brief notes along these lines entered on the right hand page of the topography book will be found worth while. A sample of the topography and material survey notes is shown on sheet No. 10. In the topography book as in the transit and level note books entries must be made showing the name of the road that the survey notes are made for, and a daily entry made as to the date, and party. These notes should be kept in a neat concise form.

PRELIMINARY ESTIMATES

Methods and Determination of Quantities

The preliminary estimates of quantities and costs are usually made up at the chief engineer's office from the field data secured from the preliminary survey, although for the purpose of balancing the cost of one road against another, approximate estimates may be made in the field by any practical method. In the office the excavation quantities are determined graphically from the profile, taking into account the center cut and side slopes, and the area of grubbing and clearing is determined in a similar manner.

Estimate Prices

No estimate of the unit cost of doing any particular piece of work can be prescribed in advance of knowledge as to the nature of the work, its location and other affecting conditions. These unit prices are decided by the chief engineer at the time the estimates are made up, but the field engineer should, however, in submitting his report give any information that he may have relative to the contract cost of similar work, which has recently been or is being done in that section, and such contract prices if any as might be used as a basis for comparative estimates on the cost of different roads which may be required in the field.

Method of Preparation

Field estimates may be prepared on the usual form and submitted to the Chief Engineer for consideration. Estimates prepared in the engineer's office will be made up in accordance with the regular prescribed form and such methods are not shown herein. Indexes give reference to the source of the data, and field notes, books and sketches which are used in connection therewith are preserved for further reference if such is necessary.

THE REVERSE LOOP

The reverse loop or true hairpin curve is the most economical manner of reversing the direction of the road on a relatively steep transverse slope when such change in direction is for any reason necessary. While the curvature in the hairpin curve is more than in a plain or so-called switchback curve the excavation and fill quantities, due to quick reduction of excessive cut and excessive fill, are less than in a switchback curve of the same radius; and if the short connecting tangents are provided and the correct superelevations given the hairpin curve, it rides fully as well and is a safer curve than the plain switchback curve usually constructed. For these reasons the true hairpin curve should be used when a reverse change in direction is required on steep transverse slopes or where the maximum amount of road center-line distance is desired in the minimum of space. For two-way auto travel the minimum radii of all curves should be 50 feet and wherever practicable, and on relatively flat side slopes (10 degrees or less) the radii of the various curves should be increased up to 100 feet. These typical layouts of a reverse loop curve are shown in the drawing so labeled. All curves on the hairpin should always be fully banked as shown on the superelevation graph. Wherever possible the tangents T_2—C_3, T_3—PC, PT—C_6 and T_6—C_7 should be provided, but if on account of lack of space such is not practicable and the curves are run in with *PRC's*, then the runoff for the superelevation will be on the curve and cared for by warping the surface as shown in the formula on the runoff chart. In most cases where rock is available and

the slopes are steep it will be found desirable to build walls on the lower sides of the loops, and when this is done position of the loop center C, should be moved down hill below the medial line M-PI sufficiently to balance the cut and fill quantities.

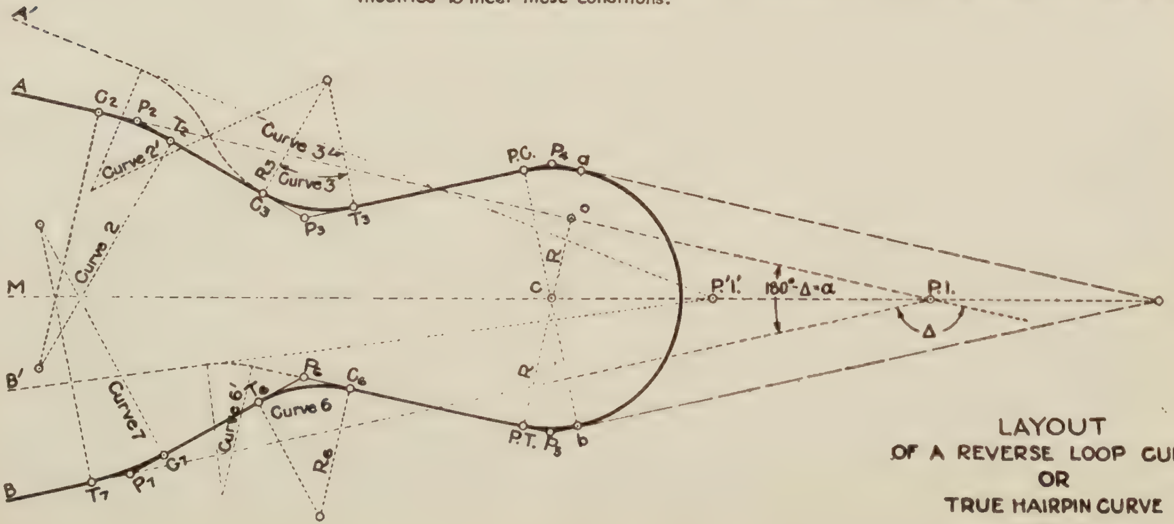
There are many different ways of laying out a hairpin curve, and just what method can best be used will, of course, depend upon the topographical conditions of the curve site in question. An example of one method which may in many cases be followed is explained as follows: Assume a fairly uniform transverse slope exists with the general tangents A-PI and B-PI located and intersecting as shown at PI. Also assume that the line is being run from A towards B via PI. (In preliminary or final locations the PI of the main tangents A-PI and B-PI is seldom occupied in laying out the hairpin.) The transit line is run to a predetermined point o which would be about opposite the PC (marked a on the sketch) of a common curve of predecided radius $= R$. With A as a back-sight, turn a right angle toward center of the curve C. The radius of the main curve R has been previously decided upon as the largest that would be justified—and not less than 50 feet—consideration being given to the transverse slope, cuts and fills for the different possible radii. Also the approximate best position for the center of the main curve picked out—this is done by swinging a tape length R about different centers until the best supported curve is secured. On regular transverse slopes C is usually about midway in elevation between points a and b on the curve.) Definitely locate the center C on this line. Plunge the instrument and with the distance R measured from C set a. Occupy a with instrument. Select point P_3, which should be about as far to the right of tangent A-PI as a is to the left of this tangent, and at a distance that will provide superelevation runoff distance for the main curve R and the curve 3 that will be established. Also provide for the subtangent P_3—T_3. Swing the radius R from C to a position PC, which shall be so located that the radius line will be approximately normal to the line PC—P_3. With the instrument plate clamped at 90° 0′ backsight on C; deflect to, set and center PC. Occupy

NOTE - The minimum tangent distance, T_2-C_3, etc., desirable is not less than the run off for Curve 2 plus the run off for Curve 3 as required by the Standard Superelevation Chart.

When on account of conditions it is not possible to have tangents T_2-C_3, T_3-P.C., etc., then the run off shall be cared for by warping the curves for a distance on each side of the P.R.C. inversely proportionate to the radii and as necessary for the superelevation for that radius. Or where a tangent of less than the desirable minimum is obtainable, the run off will be cared for by the formula given on the Standard Superelevation Chart.

As shown in the sketch several of the curves have a radius equal to R, but R_2, R_3, R_6, R_7 and R may all be different, which of course make subtangents, tangents and angles different.

Frequently tangents and main curve will occupy unsymmetrical positions similar to those shown by dotted tangent lines A′-P.I.′ or B′-P.I.′, in which case the approach curves will be changed as indicated by dotted lines and the layout notes in the instructions will have to be modified to meet these conditions.



LAYOUT
OF A REVERSE LOOP CURVE
OR
TRUE HAIRPIN CURVE
NO SCALE

PC. Plunge; backsight on *a*; transit, and turn off a deflection equal to that used at *a* in setting *PC*. The instrument should now be lining on, or about on, P_3 and the sight line will be tangent to the main curve. Reset, if necessary, P_3 and center. Check correctness of tangent position by turning 90° 0′ to *C*. Occupy P_3. Pick out point P_2 on main tangent, at such distance as to provide subtangent length and superelevation runoff for both curves *3* and *2*. Plunge instrument; back sight on *PC*; transit; deflect to P_2 and center P_2. The deflection angle that tangent P_3—P_2 makes with the main tangent *A*—*PI* will be equal to the difference between the sum of the deflections at *a* and *PC* and the angle just turned off to P_2. Select the curve radius and figure the curve properties for the curves *2* and *3*, providing for superelevation runoff distance for both curves. Pick up the stationing from the main tangent and set the *PC's* and *PT's* and externals for each curve, also set the station stakes around to the main curve *PC*. From here on swing the radius R and measure the cord distances for the sub-stations and set the stakes on the main curve to the point selected for the *PT* from which point on follow the general procedure just prescribed in laying out the rest of the curve up to P_7. When P_7 is set occupy with the instrument and after setting the next *PI* about on the main tangent *B* and running in the station stakes, etc., turn off and record the angle *B* P_7 P_2 then occupy P_2 and record angle *A* P_2 P_7 and chain and record the distance P_2—P_7.

A well qualified locator, experienced in laying out hairpin curves, probably would not follow the methods above detailed; but instead would run the hairpin in progressively and somewhat as follows: Select the center of the main curve *C* and decide on the radius for the curve. Mark on the ground the approximate desired position of P_2, P_3, P_4, P_5, P_6 and P_7. Then with the instrument at P_2 deflect to P_3, set and center P_3. Lay out curve *2*. Stake out tangent T_2—C_3. Occupy P_3. Deflect to P_4; set and center P_4. Lay out curve *3*. Stake tangent T_3—*PC*, set and center *PC*. Occupy *PC*. From T_3—*PC* turn 90° 0′. Measure *R*, set and center *C*. Occupy *C*. Backsight on *PC*, swing through

arc to PT, measure R from C and set and center PT. Set by chain and tape sub-stations on main curve. Occupy PT. Measure angle C, PT, PC. From C turn off 90° and locate P_6. Stake tangent PT—C_6. Occupy P_6. Deflect to P_7, set and center P_7. Lay out curve 6. Stake tangent T_6—C_7. Occupy P_7 on main tangent ahead and lay out curve and set PI ahead.

Whatever method may be used in laying out the curve, it will be found necessary usually to make some minor adjustments to secure the best results. For instance, should it have been found that the angle corresponding to $A\ P_4\ P_3$ and the length corresponding to P_4—P_3 with similar angle on the B leg, brings the fill at P_3 into the cut at P_6 or vice versa, then the points P_3 and P_6 will have to be adjusted so that this will not occur. On the other hand, it may be desirable at times to increase the angle $A\ P_4\ P_3$ and the length P_4—P_3 somewhat. The curve should always be laid out so that the cut will balance the fill and that the quantities of the cut and fill are reduced as much as possible. As previously indicated, the stakes from PC to PT are seldom set by deflection unless the curve has more than a 100-foot radius, the stakes being set instead by tape measurements on cord and radius. When the change in direction of the main tangents is not 100 or more degrees (angle $A\ PI\ B = 80$ degrees or less) there is no advantage in using the reverse loop curve instead of a plain curve.

Generally it will be found impossible to lay the curve out symmetrically on each leg of the main tangent course and usually the tangents are more apt to come in as indicated by dotted lines A'—$P'I'$, B'—$P'I'$ and the main loop curve will lie unequally with respect to main tangents. When these conditions occur the method of laying out the curves will, of course, be in general as described above, and such modifications must admit of dissimilar approach curves and necessary modifications in the determination of position of the main curve. Any qualified location transitman or location engineer will, however, readily see how these modifications may be made, and the problem in every case becomes one of how large the radii

of the different curves can be, and how the curves can be best fitted to the particular site chosen for the hairpin. To the person unacquainted with running in a hairpin curve the method outlined and indicated may appear slow and difficult, but with experience and judgment gained in locating and running in a few hairpins, the qualified locating engineer can quickly establish and run the curve in and secure economical and satisfactory results.

CHAPTER IX

CONCLUSION

IN the foregoing chapters (except Chapter VIII) the author has but attempted to take up in a more or less narrative manner the more general considerations of the various phases of modern mountain road or highway design and location, and to set forth briefly certain survey methods which years of experience in this class of work have shown to be, under most conditions, the cheapest, quickest and most complete way of securing the field data necessary to the proper design for and estimates of the cost of such roads. It is fully realized that the consideration, even in a general way, of mountain highway location opens up an unlimited opportunity for study and discussion and the expression of different opinions, methods, and conclusions relative to this field of work. It is earnestly hoped that these few notes and suggestions will bring about a more intelligent, careful and complete consideration by the engineers of this country of this most important phase of highway development; that methods superior to any yet found will be developed as a consequence; that this work shall be done only under the direction of engineers fully qualified by experience and ability; that the decision as to standards and routes shall be vested only in qualified engineers; that the types, class and architecture of our mountain highways and highway structures shall be of the highest; and that the civil engineering profession will be accorded public recognition commensurate with the importance of the work it is doing in this field. If all or even any of these desires shall be realized, then the author will feel that he and the other engineers who have followed with him this work through the extreme efforts, dangers, and privations incident to mountain highway location and the

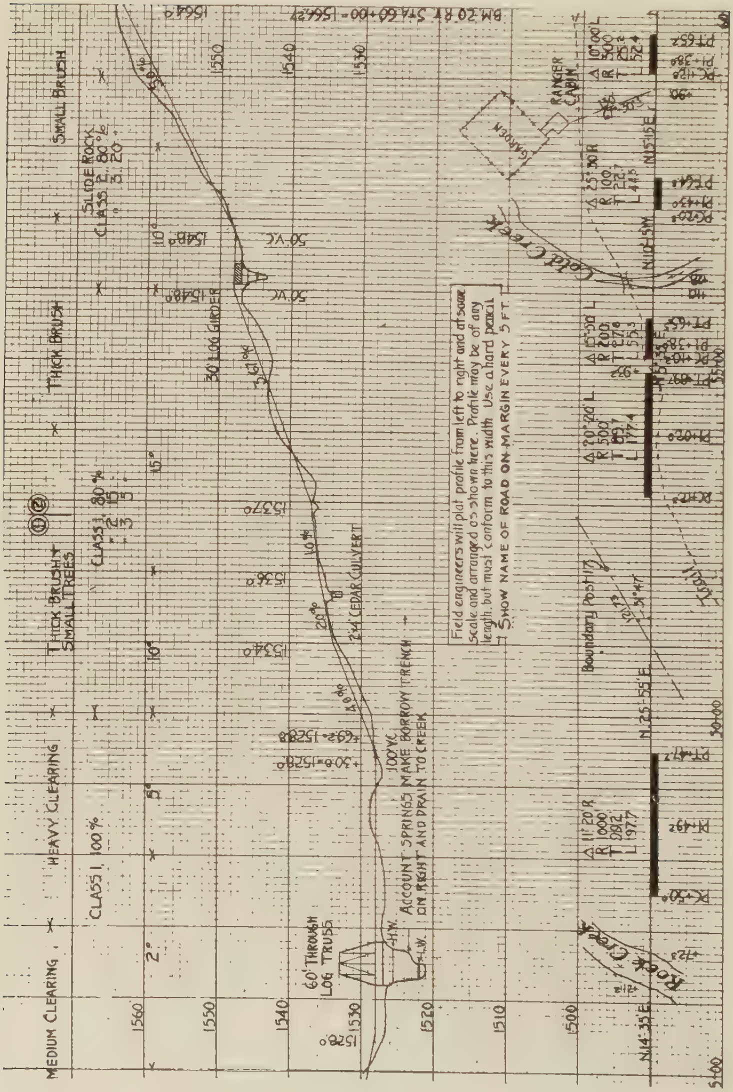
many disappointments that come to those that strive for the best obtainable and perhaps without the encouragement of sympathetic appreciation or understanding, are, after all, sufficiently rewarded and that the difficulties have been but efforts and incidents of a worth-while work.

DRAWINGS, TABLES, GRAPHS, ETC.

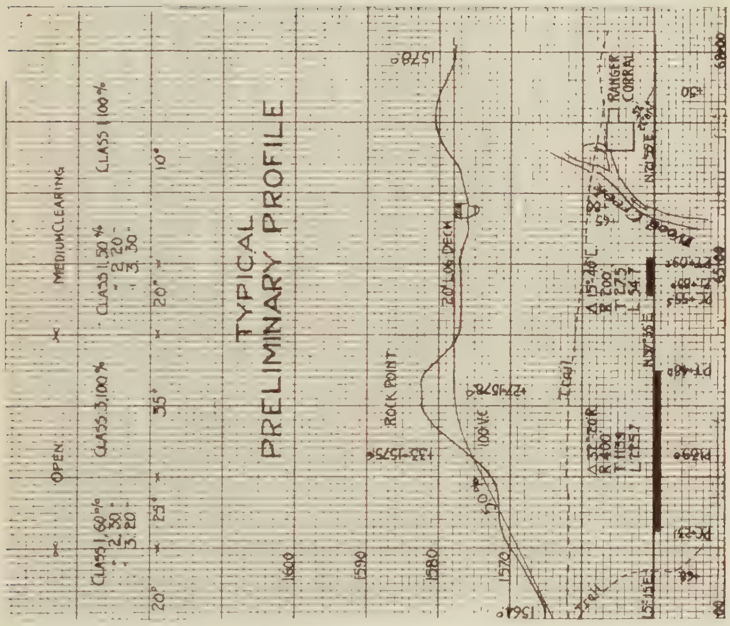
The following drawings, tables, maps, graphs, etc., are referred to in the Notes on Mountain Highway Location and are submitted as examples of drawings, formulae, tables, graphs, etc., that can be advantageously used in connection with preliminary mountain highway location. They are:

1. Typical preliminary profile.
2. Side hill excavation area graphs, 20 ft. base, sidecut slopes 1:1.
3. Curve formulae.
4. Functions of *PI* angles for 100 ft. radius.
5. Tangent offsets and tangent distances graph.
6. Tangent offsets and curve distances graph.
7. Deflections and chords for various radii curves.
8. Superelevation for road curves graph.
9. Suggested standard road sections for mountain highways.
10. Sample pages of preliminary location, topography and classification notes.
11. Arrangement for bridge site survey and design data.
12. Alignment map of difficult highway location, showing use of hairpin curves.

Page 257 attaches here.



Typical Preliminary Profile.



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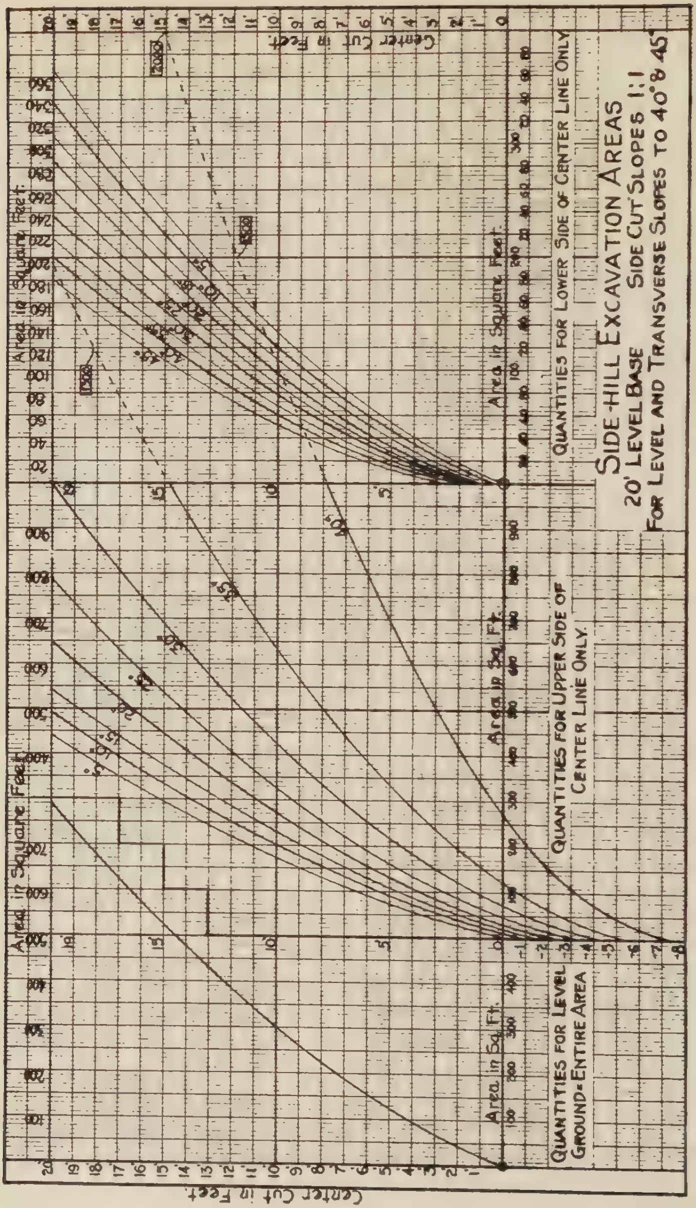
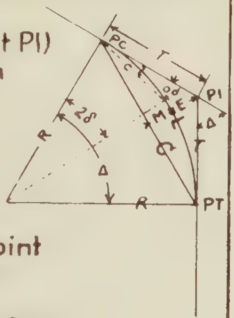


Side Hill Excavation Area Graphs, 20-Ft. Base, Side Cut Slopes 1:1.

CURVE FORMULAS

Definitions

Δ = Total Deflection for Curve (at PI)
PI = Point of Tangent Intersection
R = Radius
E = External Distance
T = Tangent Distance
PC = Point of Curvature
L = Total Curve Length
PT = Point of Tangency
l = Length of Curve to Any Point
δ = Deflection Angle to Same
c = Chord for Same
od = Offset from Tangent for Same
C = Long Chord
M = Middle Ordinate



For Arc Measured Curves:

$E = R\,\text{exsec}\,\tfrac{1}{2}\Delta = R(1-\cos\tfrac{1}{2}\Delta)\div\cos\tfrac{1}{2}\Delta$; Sta = $\tfrac{1}{2}$L + PC
$T = R\tan\tfrac{1}{2}\Delta$
PC = PI − T
$L = R\Delta\,0.0174533$, in feet Along Curve
PT = PC + L
$\delta = l\div(2R\,0.0174533)$ in Degrees & Decimals
$c = 2R\sin\delta$
$od = c\sin\delta = 2R\sin^2\delta = R\,\text{vers}\,2\delta = R(1-\cos 2\delta)$
$C = 2R\sin\tfrac{1}{2}\Delta$
$M = R\,\text{vers}\,\tfrac{1}{2}\Delta = R(1-\cos\tfrac{1}{2}\Delta)$

For Railroad Curves

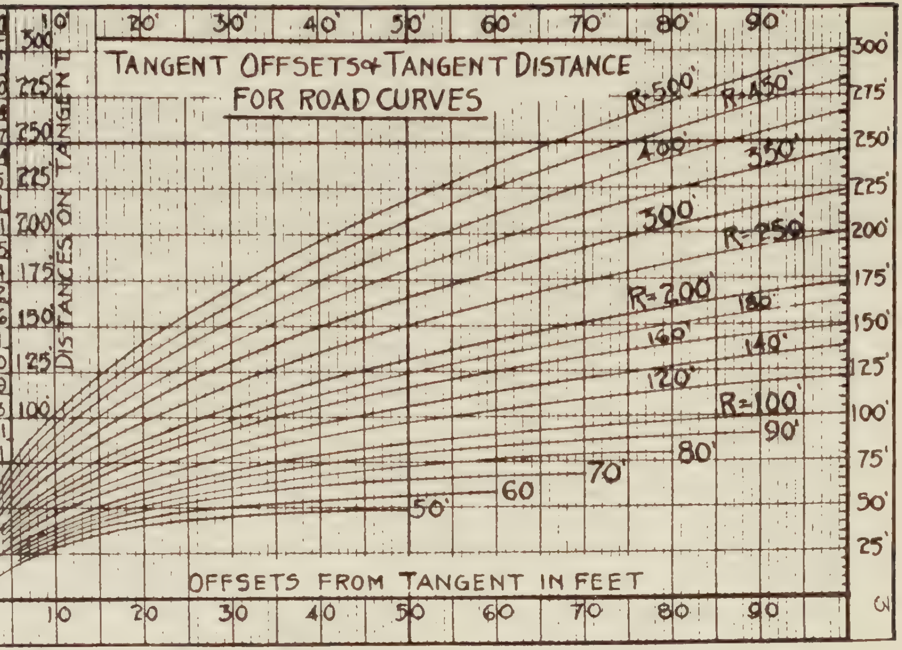
d = Degree of Curve
L = Length by chords = $\tfrac{1}{2}\Delta\div\delta$ for Chord Used
$\delta = \sin^{-1} c/2R$, or $\sin\delta = c/2R$
$R = 50/\sin\tfrac{1}{2}d = T\cot\tfrac{1}{2}\Delta$, for 100' chords
$R = 25/\sin\tfrac{1}{4}d = 25\,\text{cosec}\,\tfrac{1}{4}d$, for 50' chords
$R = 12.5/\sin\tfrac{1}{8}d = 12.5\,\text{cosec}\,\tfrac{1}{4}d$, for 25' chords
$R = 5/\sin\tfrac{1}{20}d = 5\,\text{cosec}\,\tfrac{1}{20}d$, for 10' chords
Other Formulas as Above

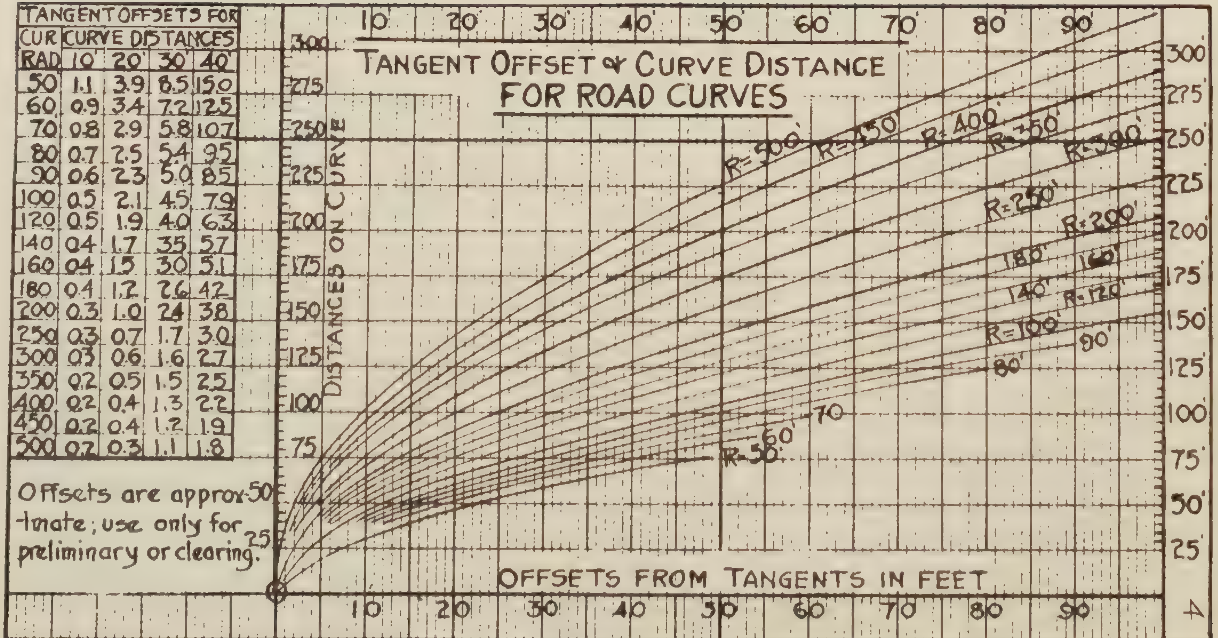
Use deflections in open country
Use offsets in brush

FUNCTIONS OF PI ANGLES FOR 100' RADIUS

Δ°	E (ft)	T (ft)	L (ft)	Δ°	E (ft)	T (ft)	L (ft)
5°	0.1	4.37	8.73	70	22.1	70.02	122.17
6	0.1	5.24	10.47	71	22.8	71.33	123.92
7	0.2	6.12	12.22	72	23.6	72.65	125.66
8	0.2	6.99	13.96	73	24.4	74.00	127.41
9	0.3	7.87	15.71	74	25.2	75.36	129.15
10	0.4	8.75	17.45	75	26.0	76.73	130.90
11	0.5	9.63	19.20	76	26.9	78.13	132.65
12	0.5	10.51	20.94	77	27.8	79.54	134.39
13	0.6	11.39	22.69	78	28.7	80.98	136.14
14	0.7	12.28	24.43	79	29.6	82.43	137.88
15	0.8	13.16	26.18	80	30.5	83.91	139.63
16	1.0	14.05	27.93	81	31.5	85.41	141.37
17	1.1	14.95	29.67	82	32.5	86.93	143.12
18	1.2	15.84	31.42	83	33.5	88.47	144.86
19	1.4	16.73	33.16	84	34.6	90.04	146.61
20	1.5	17.63	34.91	85	35.6	91.63	148.35
21	1.7	18.53	36.65	86	36.7	93.25	150.10
22	1.8	19.44	38.40	87	37.9	94.90	151.84
23	2.0	20.35	40.14	88	39.0	96.57	153.59
24	2.2	21.26	41.89	89	40.2	98.27	155.33
25	2.4	22.17	43.63	90	41.4	100.00	157.08
26	2.6	23.09	45.38	91	42.7	101.76	158.82
27	2.8	24.01	47.12	92	44.0	103.55	160.57
28	3.0	24.93	48.87	93	45.3	105.38	162.32
29	3.2	25.86	50.61	94	46.6	107.24	164.06
30	3.4	26.80	52.36	95	48.0	109.13	165.81
31	3.8	27.73	54.09	96	49.4	111.06	167.55
32	4.0	28.65	55.83	97	50.9	113.03	169.30
33	4.3	29.62	57.58	98	52.4	115.04	171.04
34	4.6	30.57	59.32	99	54.0	117.09	172.79
35	4.9	31.53	61.07	100	55.6	119.18	174.53
36	5.1	32.49	62.82	101	57.2	121.31	176.28
37	5.4	33.46	64.56	102	58.9	123.49	178.02
38	5.8	34.43	66.31	103	60.6	125.72	179.77
39	5.1	35.41	68.05	104	62.4	127.99	181.51
40	6.4	36.40	69.81	105	64.3	130.32	183.26
41	6.8	37.39	71.56	106	66.2	132.70	185.00
42	7.1	38.39	73.30	107	68.1	135.14	186.75
43	7.5	39.39	75.05	108	70.1	137.64	188.50
44	7.9	40.40	76.79	109	72.2	140.20	190.24
45	8.2	41.42	78.54	110	74.3	142.82	191.99
46	8.6	42.45	80.29	111	76.6	145.50	193.73
47	9.0	43.48	82.03	112	78.8	148.26	195.48
48	9.5	44.52	83.78	113	81.2	151.08	197.22
49	9.9	45.57	85.52	114	83.6	153.99	198.97
50	10.3	46.63	87.27	115	86.1	156.97	200.71
51	10.8	47.70	89.01	116	88.7	160.03	202.46
52	11.3	48.77	90.76	117	91.4	163.19	204.20
53	11.7	49.86	92.50	118	94.2	166.43	205.95
54	12.2	50.95	94.24	119	97.0	169.77	207.69
55	12.7	52.06	95.99	120	100.0	173.21	209.44
56	13.3	53.17	97.74	121	103.1	176.75	211.18
57	13.8	54.30	99.48	122	106.3	180.41	212.93
58	14.3	55.43	101.23	123	109.6	184.18	214.68
59	15.0	56.56	102.98	124	113.0	188.07	216.42
60	15.5	57.74	104.72	125	116.6	192.10	218.17
61	16.1	58.91	106.47	126	120.3	196.26	219.91
62	16.7	60.09	108.21	127	124.1	200.57	221.66
63	17.3	61.28	109.96	128	128.1	205.03	223.40
64	17.9	62.49	111.70	129	132.3	209.65	225.15
65	18.6	63.71	113.45	130	136.6	214.45	226.85
66	19.2	64.94	115.19	131	141.1	219.43	228.64
67	19.9	66.19	116.94	132	145.9	224.60	230.38
68	20.6	67.45	118.68	133	150.8	229.98	232.13
69	21.3	68.73	120.43	134	155.9	235.59	233.87

OFFSETS TO CURVES FROM TANGENT AT DISTANCES OF						
CUR. RAD.	5'	10'	15'	20'	25'	30'
50'	.23	1.01	2.34	4.17	6.64	10.00
60'	.22	.84	1.91	3.43	5.45	8.04
70'	.18	.74	1.63	2.94	4.64	6.77
80	.16	.63	1.42	2.54	4.01	5.84
90	.14	.56	1.26	2.25	3.48	5.15
100	.13	.50	1.13	2.02	3.18	4.61
120	.11	.42	.95	1.68	2.55	3.81
140	.09	.36	.81	1.44	2.29	3.25
160	.08	.31	.71	1.25	1.96	2.84
180	.07	.28	.63	1.11	1.75	2.52
200	.06	.25	.56	1.01	1.57	2.26
250	.05	.20	.45	.80	1.25	1.81
300	.04	.17	.36	.67	1.05	1.50
350	.04	.14	.33	.57	.90	1.29
400	.04	.12	.28	.50	.76	1.13
450	.03	.12	.26	.45	.70	1.01
500	.03	.11	.23	.41	.53	.91





TANGENT OFFSETS FOR				
CUR	CURVE DISTANCES			
RAD	10'	20'	30'	40'
50	1.1	3.9	8.5	15.0
60	0.9	3.4	7.2	12.5
70	0.8	2.9	5.8	10.7
80	0.7	2.5	5.4	9.5
90	0.6	2.3	5.0	8.5
100	0.5	2.1	4.5	7.9
120	0.5	1.9	4.0	6.3
140	0.4	1.7	3.5	5.7
160	0.4	1.5	3.0	5.1
180	0.4	1.2	2.6	4.2
200	0.3	1.0	2.4	3.8
250	0.3	0.7	1.7	3.0
300	0.3	0.6	1.6	2.7
350	0.2	0.5	1.5	2.5
400	0.2	0.4	1.3	2.2
450	0.2	0.4	1.2	1.9
500	0.2	0.3	1.1	1.8

DEFLECTIONS AND CHORDS FOR CURVES OF VARIOUS RADII

For True Distances Along the Curve Of

RADII		1'	2'	3'	4'	5'	6'
50	δ	0°34.4'	1°08.8'	1°43.1'	2°17.5'	2°51.9'	3°26.3'
	c	1.00	2.00	3.00	4.00	5.00	6.00
55	δ	0°31.2'	1°02.5'	1°33.7'	2°05.0	2°36.3'	3°07.5'
	c	1.00	2.00	3.00	4.00	5.00	6.00
60	δ	0°28.6'	0°57.3	1°25.9	1°54.6'	2°23.2'	2°51.9'
	c	1.00	2.00	3.00	4.00	5.00	6.00
65	δ	0°26.4'	0°52.9'	1°19.3'	1°45.8'	2°12.2'	2°38.7'
	c	1.00	2.00	3.00	4.00	5.00	6.00
70	δ	0°24.6'	0°49.1'	1°13.7'	1°38.2'	2°02.7'	2°27.3'
	c	1.00	2.00	3.00	4.00	5.00	6.00
75	δ	0°22.9'	0°45.8	1°08.7'	1°31.7'	1°54.6'	2°17.5'
	c	1.00	2.00	3.00	4.00	5.00	7.00
80	δ	0°21.5'	0°43.0'	1°04.4'	1°26.0'	1°47.4'	2°08.9'
	c	1.00	2.00	3.00	4.00	5.00	6.00
85	δ	0°20.2'	0°40.4'	1°00.7'	1°20.9'	1°41.1'	2°01.3'
	c	1.00	2.00	3.00	4.00	5.00	6.00
90	δ	0°19.1'	0°38.2'	0°57.2'	1°16.4'	1°35.5'	1°54.6'
	c	1.00	2.00	3.00	4.00	5.00	6.00
95	δ	0°18.1'	0°36.2'	0°54.2'	1°12.4'	1°30.5'	1°48.6'
	c	1.00	2.00	3.00	4.00	5.00	6.00
100	δ	0°17.2'	0°34.4'	0°51.5	1°08.8'	1°25.9'	1°43.1'
	c	1.00	2.00	3.00	4.00	5.00	6.00
110	δ	0°15.6'	0°31.2'	0°46.9'	1°02.5'	1°18.1'	1°33.7'
	c	1.00	2.00	3.00	4.00	5.00	6.00
120	δ	0°14.3'	0°28.6'	0°43.0'	0°57.3'	1°11.6'	1°25.9'
	c	1.00	2.00	3.00	4.00	5.00	6.00
130	δ	0°13.2'	0°26.4'	0°39.7'	0°52.9'	1°06.1'	1°19.3
	c	1.00	2.00	3.00	4.00	5.00	6.00
140	δ	0°12.3'	0°24.6	0°36.8'	0°49.1'	1°01.4'	1°13.7'
	c	1.00	2.00	3.00	4.00	5.00	6.00
150	δ	0°11.5'	0°22.9'	0°34.4'	0°45.8'	0°57.3'	1°08.8'
	c	1.00	2.00	3.00	4.00	5.00	6.00
160	δ	0°10.7'	0°21.5'	0°32.2'	0°42.9'	0°53.7'	1°04.5'
	c	1.00	2.00	3.00	4.00	5.00	6.00
170	δ	0°10.1'	0°20.2'	0°30.3'	0°40.4'	0°50.5'	1°00.7
	c	1.00	2.00	3.00	4.00	5.00	6.00
180	δ	0°09.5'	0°19.1'	0°28.6'	0°38.2	0°47.7'	0°57.3'
	c	1.00	2.00	3.00	4.00	5.00	6.00
190	δ	0°09.0'	0°18.1'	0°27.1'	0°36.1'	0°45.2'	0°54.3'
	c	1.00	2.00	3.00	4.00	5.00	6.00
200	δ	0°08.6'	0°17.2'	0°25.8	0°34.4'	0°43.0'	0°51.6'
	c	1.00	2.00	3.00	4.00	5.00	6.00
220	δ	0°07.8'	0°15.6'	0°23.4'	0°31.2'	0°39.1	0°46.9'
	c	1.00	2.00	3.00	4.00	5.00	6.00
240	δ	0°07.2'	0°14.3'	0°21.5'	0°28.6'	0°35.8	0°43.0'
	c	1.00	2.00	3.00	4.00	5.00	6.00
260	δ	0°06.6	0°13.2'	0°19.8'	0°26.4'	0°33.0	0°39.7
	c	1.00	2.00	3.00	4.00	5.00	6.00
280	δ	0°06.1'	0°12.3'	0°18.4'	0°24.6'	0°30.7'	0°36.8
	c	1.00	2.00	3.00	4.00	5.00	6.00
300	δ	0°05.7	0°11.5'	0°17.2'	0°22.9'	0°28.7'	0°34.4'
	c	1.00	2.00	3.00	4.00	5.00	6.00
350	δ	0°04.9	0°09.8'	0°14.7'	0°19.6'	0°24.5'	0°29.5'
	c	1.00	2.00	3.00	4.00	5.00	6.00
400	δ	0°04.3'	0°08.6'	0°12.9'	0°17.2'	0°21.5	0°25.8'
	c	1.00	2.00	3.00	4.00	5.00	6.00
450	δ	0°03.8'	0°07.6'	0°11.5'	0°15.3'	0°19.1'	0°22.9'
	c	1.00	2.00	3.00	4.00	5.00	6.00
500	δ	0°03.4	0°06.9'	0°10.5'	0°13.8'	0°17.2'	0°20.6'
	c	1.00	2.00	3.00	4.00	5.00	6.00

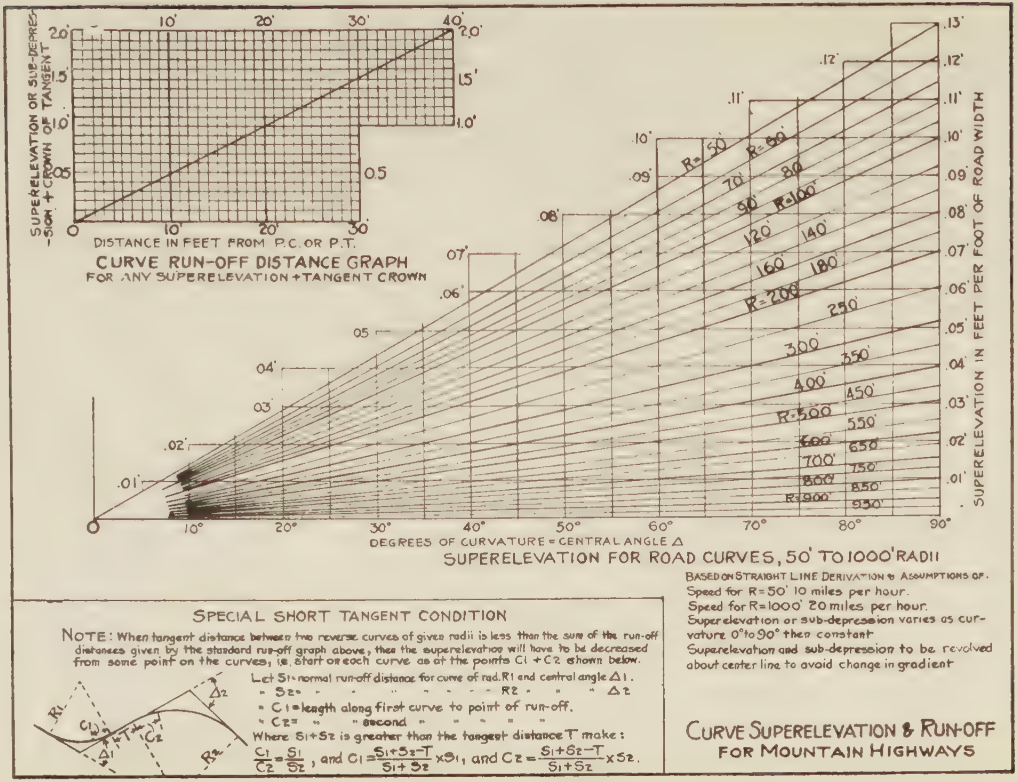
Page 264 joins here.

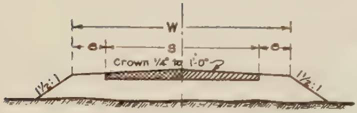
DEFLECTIONS AND CHORDS FOR CURVES OF VARIOUS RADII

For True Distances Along the Curve Of

Page 263 joins here.

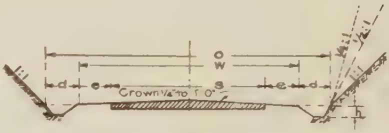
7′	8′	9′	10′	20′	25′	50′	RADII
4°00.7′ 7.00	4°35.0′ 8.00	5°09.4′ 9.00	5°43.8′ 9.99	11°27.9′ 19.88	14°19.4′ 24.74	28°38.9′ 47.94	50
3°38.8′ 7.00	4°10.0′ 8.00	4°41.3′ 9.00	5°12.5′ 9.99	10°25.2′ 19.90	13°01.3′ 24.78	26°02.9′ 48.30	55
3°20.5′ 7.00	3°49.1′ 8.00	4°17.8′ 9.00	4°46.5′ 9.99	9°33.0′ 19.91	11°56.1′ 24.83	23°52.4′ 48.57	60
3°05.1′ 7.00	3°31.6′ 8.00	3°58.0′ 9.00	4°24.4′ 9.99	8°48.9′ 19.92	11°01.1′ 24.84	22°02.2′ 48.78	65
2°51.9′ 7.00	3°16.4′ 8.00	3°41.0′ 9.00	4°05.6′ 10.00	8°11.1′ 19.93	10°13.9′ 24.86	20°27.8′ 48.95	70
2°40.4′ 7.00	3°03.3′ 8.00	3°26.3′ 9.00	3°49.2′ 10.00	7°38.3′ 19.94	9°32.9′ 24.88	19°05.9′ 49.08	75
2°30.4′ 7.00	2°51.9′ 8.00	3°13.4′ 9.00	3°34.8′ 10.00	7°09.7′ 19.95	8°57.1′ 24.90	17°54.3′ 49.19	80
2°21.5′ 7.00	2°41.8′ 8.00	3°02.0′ 9.00	3°22.2′ 10.00	6°44.4′ 19.95	8°25.5′ 24.91	16°51.1′ 49.28	85
2°13.7′ 7.00	2°32.8′ 8.00	2°51.9′ 9.00	3°11.0′ 10.00	6°22.0′ 19.95	7°57.4′ 24.92	15°54.8′ 49.35	90
2°06.6′ 7.00	2°24.7′ 8.00	2°42.8′ 9.00	3°00.9′ 10.00	6°01.9′ 19.96	7°32.3′ 24.93	15°04.7′ 49.43	95
2°00.3′ 7.00	2°17.5′ 8.00	2°34.7′ 9.00	2°51.9′ 10.00	5°43.9′ 19.97	7°09.7′ 24.94	14°19.4′ 49.47	100
1°49.4′ 7.00	2°05.0′ 8.00	2°20.6′ 9.00	2°36.3′ 10.00	5°12.5′ 19.97	6°30.6′ 24.94	13°01.3′ 49.56	110
1°40.3′ 7.00	1°54.6′ 8.00	2°08.9′ 9.00	2°23.2′ 10.00	4°46.5′ 19.98	5°58.1′ 24.95	11°56.2′ 49.64	120
1°32.5′ 7.00	1°45.8′ 8.00	1°59.0′ 9.00	2°12.2′ 10.00	4°24.4′ 19.98	5°30.5′ 24.96	11°01.1′ 49.69	130
1°25.9′ 7.00	1°38.2′ 8.00	1°50.5′ 9.00	2°02.8′ 10.00	4°05.5′ 19.98	5°06.9′ 24.96	10°13.9′ 49.74	140
1°20.0′ 7.00	1°31.7′ 8.00	1°43.1′ 9.00	1°54.6′ 10.00	3°49.2′ 19.99	4°47.1′ 24.97	9°32.9′ 49.76	150
1°15.2′ 7.00	1°25.9′ 8.00	1°36.7′ 9.00	1°47.4′ 10.00	3°34.9′ 19.99	4°28.6′ 24.98	8°57.1′ 49.79	160
1°10.8′ 7.00	1°20.9′ 8.00	1°31.0′ 9.00	1°41.1′ 10.00	3°22.2′ 19.99	4°12.8′ 24.98	8°25.5′ 49.82	170
1°06.8′ 7.00	1°16.4′ 8.00	1°25.9′ 9.00	1°35.5′ 10.00	3°11.0′ 19.99	3°58.7′ 24.98	7°57.5′ 49.85	180
1°03.3′ 7.00	1°12.4′ 8.00	1°21.4′ 9.00	1°30.5′ 10.00	3°00.9′ 19.99	3°46.2′ 24.98	7°32.3′ 49.87	190
1°00.1′ 7.00	1°08.8′ 8.00	1°17.3′ 9.00	1°25.9′ 10.00	2°51.9′ 19.99	3°34.8′ 24.98	7°09.7′ 49.89	200
0°54.7′ 7.00	1°02.5′ 8.00	1°10.3′ 9.00	1°18.1′ 10.00	2°36.3′ 19.99	3°15.3′ 24.98	6°30.7′ 49.90	220
0°50.1′ 7.00	0°57.3′ 8.00	1°04.5′ 9.00	1°11.6′ 10.00	2°23.2′ 19.99	2°59.1′ 24.99	5°58.1′ 49.91	240
0°46.3′ 7.00	0°52.0′ 8.00	0°59.5′ 9.00	1°06.1′ 10.00	2°12.2′ 19.99	2°45.3′ 24.99	5°30.6′ 49.92	260
0°43.0′ 7.00	0°49.1′ 8.00	0°55.2′ 9.00	1°01.4′ 10.00	2°02.8′ 19.99	2°33.5′ 24.99	5°06.9′ 49.93	280
0°40.1′ 7.00	0°45.8′ 8.00	0°51.6′ 9.00	0°57.3′ 10.00	1°54.6′ 20.00	2°23.2′ 24.99	4°46.5′ 49.94	300
0°34.4′ 7.00	0°39.3′ 8.00	0°44.2′ 9.00	0°49.1′ 10.00	1°38.2′ 20.00	2°02.8′ 24.99	4°05.6′ 49.96	350
0°30.1′ 7.00	0°34.4′ 8.00	0°38.7′ 9.00	0°43.0′ 10.00	1°25.9′ 20.00	1°47.4′ 24.99	3°34.9′ 49.97	400
0°26.7′ 7.00	0°30.6′ 8.00	0°34.4′ 9.00	0°38.2′ 10.00	1°16.4′ 20.00	1°35.5′ 25.00	3°10.9′ 49.98	450
0°24.1′ 7.00	0°27.5′ 8.00	0°30.9′ 9.00	0°34.4′ 10.00	1°08.8′ 20.00	1°26.0′ 25.00	2°51.9′ 49.98	500


SUPERELEVATION OR SUB-DEPRESSION + CROWN OF TANGENT
DISTANCE IN FEET FROM P.C. OR P.T.
CURVE RUN-OFF DISTANCE GRAPH
FOR ANY SUPERELEVATION + TANGENT CROWN
SUPERELEVATION IN FEET PER FOOT OF ROAD WIDTH
DEGREES OF CURVATURE = CENTRAL ANGLE Δ
SUPERELEVATION FOR ROAD CURVES, 50' TO 1000' RADII
BASED ON STRAIGHT LINE DERIVATION & ASSUMPTIONS OF.
Speed for R=50' 10 miles per hour.
Speed for R=1000' 20 miles per hour.
Superelevation or sub-depression varies as curvature 0° to 90° then constant
Superelevation and sub-depression to be revolved about center line to avoid change in gradient
SPECIAL SHORT TANGENT CONDITION
NOTE: When tangent distance between two reverse curves of given radii is less than the sum of the run-off distances given by the standard run-off graph above, then the superelevation will have to be decreased from some point on the curves, i.e. start on each curve as at the points C1 + C2 shown below.
Let S1 = normal run-off distance for curve of rad. R1 and central angle Δ1.
" S2 = " " " " " " R2 " " Δ2
" C1 = length along first curve to point of run-off.
" C2 = " " second " " " "
Where S1+S2 is greater than the tangent distance T make:
C1/C2 = S1/S2, and C1 = (S1+S2−T)/(S1+S2) × S1, and C2 = (S1+S2−T)/(S1+S2) × S2.
CURVE SUPERELEVATION & RUN-OFF
FOR MOUNTAIN HIGHWAYS



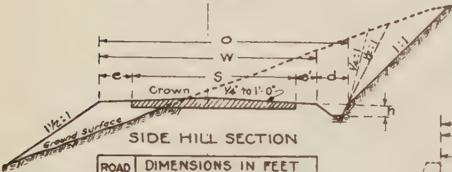
FILL SECTION

ROAD CLASS	DIMENSIONS IN FEET						
	w	s	e	e	d	h	o
I	30	20	5	5			
II	24	16	4	4			
III	16	10	3	3			
IV	12	8	2	2			



THORO CUT SECTION

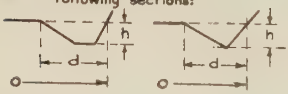
ROAD CLASS	DIMENSIONS IN FEET						
	w	s	e	e	d	h	o
I	24	20	2	2	3	1	30
II	20	16	2	2	3	1	26
III	13	10	1.5	1.5	2.5	1	18
IV	10	8	1	1	2	0.7	14

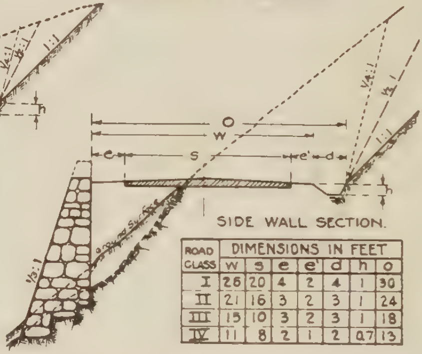


SIDE HILL SECTION

ROAD CLASS	DIMENSIONS IN FEET						
	w	s	e	e'	d	h	o
I	26	20	4	2	4	1	30
II	21	16	3	2	3	1	24
III	15	10	3	2	3	1	18
IV	11	8	2	1	2	0.7	13

NOTE- Ditch to be either of the following sections:





SIDE WALL SECTION.

ROAD CLASS	DIMENSIONS IN FEET						
	w	s	e	e'	d	h	o
I	26	20	4	2	4	1	30
II	21	16	3	2	3	1	24
III	15	10	3	2	3	1	18
IV	11	8	2	1	2	0.7	13

Note- For variations in width due to type of road and extreme conditions see Drawing 212 $\frac{8}{2}$.

ROAD STANDARDS - GENERAL

CLASS I- Width 26'-0". Surface 20'-0".-Gradient: Ruling 5%; Maximum 6%: Compensated for curvature.— Curvature: Ruling minimum 200' radius; Extreme minimum 100' radius.

CLASS II- Width 21'-0". Surface 16'-0".-Gradient: Ruling 6%; Maximum 8%; Compensated for curvature.- Curvature-Ruling minimum 100' radius; Extreme minimum 50' radius.

CLASS III - Width 15'-0". Surface 10'-0".-Turnouts: width 21'-0". Surface 16'-0".-Gradient: Ruling 6%; Maximum 8%; compensated for curvature. - Curvature: Ruling minimum 100' radius. Extreme minimum 50' radius.

CLASS IV - Width 11'-0". Surface 8'-0.- Turnouts: width 18'-0"; surface 14'-0"- Gradient: Ruling 8%; Maximum 10%; compensated for curvature.- Curvature: Ruling minimum 100' radius. Extreme minimum 50' radius.

SUGGESTED STANDARD ROAD SECTIONS FOR MOUNTAIN HIGHWAYS

STA.	L	C	R	MAT'L	CLEARING	REMARKS
	Slope °			Classification	Classification	Topog. J R Penland, C P Smith, Sept. 18, 1918 Clear-Cool
184+00	+18°		-18°	5/3 · 13/2 80/1	H/C S/T F/T ④ ㉚ H/B A/B F/B	
187+00	+18°		-18°	5/3 13/2 80/1	H/C S/T F/T ④ ㉚ H/B A/B F/B	184+25 Culvert 4x6 185+35 Culvert 2'x4'
187+50	+15°		-18°	5/3 13/2 80/1	L/C ahead A/B H/B	188+40 Culvert 2'x4'
188+50	+25°		-20°	20/3 30/2 60/1	M/C ahead SF/T ④ ㉔ H/B A/B	Key Notes
189+70	+24°		-20°	15/3 20/2 65/1	H/C ahead S/T ⑧ ㉚ H/B F/B	H/C means heavy clearing
191+50	+28°		-22°	15/3 20/2 65/1	H/C S/T ⑨ ㉚ H/B F/B W/B A/B	S/T . . spruce timber
192+20	+25°		-20°	" " "	"	F/T . . fir timber
197+00	+20°		-20°	"	"	H/B . . huckleberry brush
199+00	+17°		-17°	10/3 15/2 75/1	"	A/B . . alder brush
202+75	+23°		-17°	15/3 15/2 70/1	These symbols listed on page I are shown here for information.	F/B . . fir brush
204+00	+20°		-20°	" "		N/C . . no clearing
205+50	+22°		-18°	"	H/C S/T ⑧ ㉚ H/B F/B W/B A/B	L/C . . light clearing
206+50	+18°		-18°	"	"	M/C . . medium clearing
206+80	+28°		-28°	20/3 20/2 60/1	"	SF/T . . scattering fir
208+00	+28°		-28°	"	"	W/B . . willow brush
208+20	+28°		-18°	15/3 15/2 70/1	"	⑫ . . size of trees
209+30	+28°		-28°	"	"	
210+00	+28°		-28°	"	"	
210+60	+25°		-0.0°	"	"	Reynalds Creek bottom
210+80	+8°		-8°	100/1 Fill	N/C ahead	Right bank Reynalds Creek
211+20	+8°		-8°	Bridge	H/C ahead S/T ⑧ ㉚ H/B F/B A/B	Bridge 40' span Left bank Reynalds Creek
211+30	+15°	-3.0/3	-9.0/100 -12.0/20	100/1	H/C S/T F/T ④ ⑳ H/B F/B A/B	

Sample pages of Preliminary Location Topography and Classification Notes.

BRIDGE SITE DATA

PARK............. PROJECT .... STATION.............
STREAM DATA. Date.............. Data and survey by.............
Name of stream. .... Approximate area of watershed.............
Character of watershed.............
....
Elevation of bottom of channel on CL.............Low water elevation on CL.............
Normal high water elevation on CL.............Period.............
Extreme flood elevation on CL.............Date and frequency.............
Describe location of indications.............
Water elevation ....
Character of banks.............Does stream overflow banks?.............
Is bank protection necessary?.............Amount and character of ice and drift.............
Character of stream bed.............
Grade of channel 200.0 ft. to 500.0 ft. each side of CL.............
Is scour probable?.............
Is cutting of a new channel threatened?.............
Possible channel change and cost.............
....
Character of structural excavation.............Method.............
Probable character and elevation of satisfactory foundation. Right.............Left.............
Will piling be necessary?.............
Snow conditions ....

MAPS.

Make small scale map and profile on back of this sheet, showing trend and gradient of stream for some distance above and below site. (Ordinarily 1000.0 ft. and 500.0 ft. respectively.) Show present and proposed alignment of bridge and approaches, show channels, islands, obstructions, fences, buildings and other features.

Indicate position and direction of each photo taken.

Make contour map and profile of bridge site (not less than 1 in. = 20 ft.) using same horizontal and vertical scale in space provided, using 2.0 ft. contour interval, if possible.

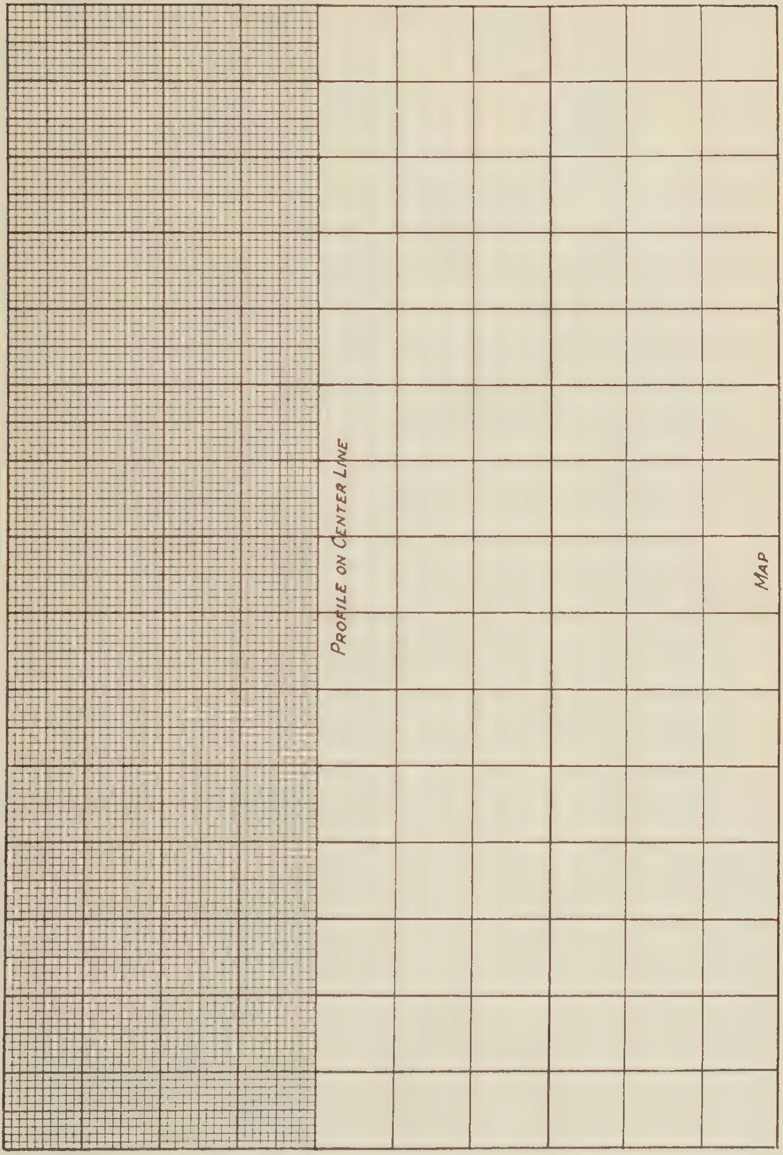
DESIGN DATA.
Describe in detail any existing structure over the stream, at or near the site.............
....
Elevation of present road grade.............Area of present waterway.............
Is new structure necessary?.............
Recommended span ....Roadway.............Type.............
Recommended clearance from highwater to lowest part of structure.............
Recommended grade elevation. (Thickness of floor system must be considered.)
....
Shoulder width of approaches.............Width of surfacing.............Type.............
Character and volume of traffic.............
Type of material available for backfill.............
How will traffic on old road be handled during construction?.............

LOCATION OF NATURAL BRIDGE MATERIALS.
Sand.............
Gravel.............
Stone.............
Logs and poles.............
Cedar.............
Tamarack.............
Fir.............
Piling.............

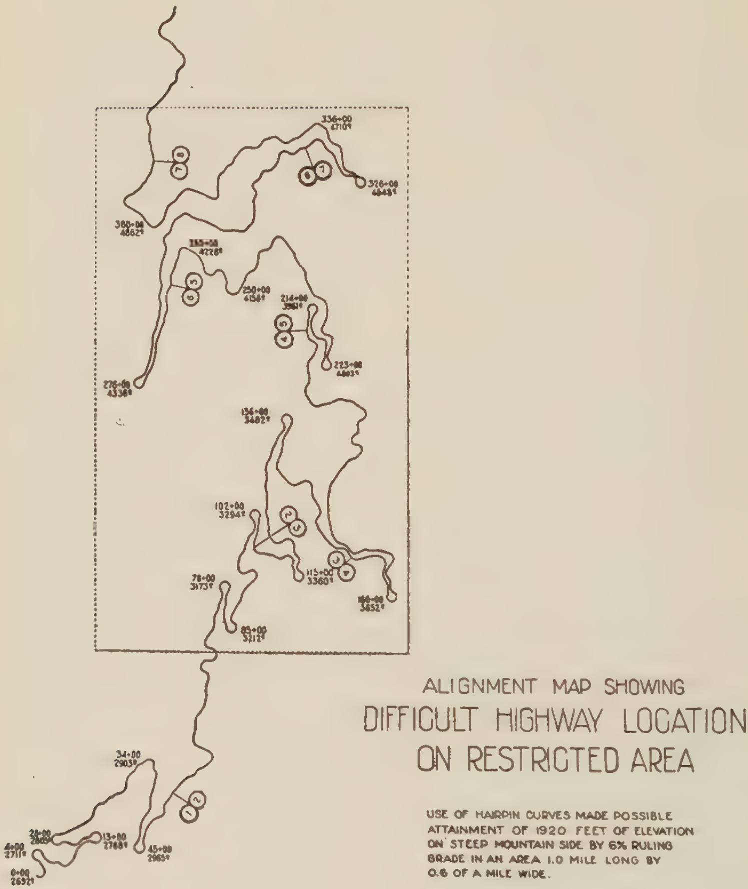
REMARKS.............
....
....
....
....
....

Page 269 attaches here.

Page 268 attaches here.



Arrangement for Bridge Site Survey and Design Data.



Alignment Map of Difficult Highway Location on Restricted Area and Use of Hairpin Curves on Mountain Highway Location.

BOOK III

Notes on Highway Surveying

COMPILED BY

W. W. CROSBY

Keeping Line and Grade Stakes Up with the Job on Location of New Roadway.

Notes on Highway Surveying

FOR the sake of convenience in connection with the foregoing text of Parts I and II, as well as for reference purposes, it has been thought best to assemble in this separate part extracts from field manuals concerning surveys; instructions concerning procedure and plans that are worth quoting in this connection; the forms established for use in highway location in one of the states that has devoted a great deal of attention to the subject; extracts from previously printed papers on location, and a bibliography or list of articles bearing on the subject printed within recent years and worth study coincidentally.

LOCATION SURVEYS

The excellent field manual of the Iowa State Highway Commission contains the following:

"GENERAL PLAN OF SURVEY

The district engineer shall go over the general plan of each survey with the chief of party and agree as to:

1. Datum to be used.
2. Point of beginning of survey and system of stationing to be used.
3. Points governing alignment.
4. Relocations.

Important bridges, cemeteries, streams and other topographical features often constitute points which will control the alignment and must always be given consideration in locating the center line of the survey.

The district engineer shall investigate fully all relocations that may appear feasible and shall instruct the chief of party to make such relocation surveys. If in doubt as to the feasibility of any relocation that

presents itself, a survey should be made. It is much better to survey a number of relocations that are later abandoned than to fail to survey one which later proves desirable.

The district engineer is responsible for outlining all relocations and having surveys made. This does not relieve the chief of party from his obligation to at all times look for opportunities to take advantage of conditions and improve the general quality of the surveys. If at any time it should appear that the district engineer has overlooked any feasible relocations or other features of the project, the chief of party should call this fact to the district engineer's attention.

The district engineer shall report fully to the general office relative to all relocations which are to be surveyed. These reports shall contain sketches of all such relocations.

Sketches should be approximate to scale so that a good idea of the proposed alignment may be obtained therefrom.

DETAILED INSTRUCTIONS

General

The chief of party should constantly bear in mind that the office man who works up the notes may have no first-hand knowledge of field conditions; he must necessarily base the design on the information contained in the notes, and the value of the completed plans will depend entirely upon the care with which the survey is made and recorded.

In the instructions which follow, a great many points have been covered, but it is impossible to anticipate all conditions. The chief of party will doubtless encounter many situations not mentioned here. To make sure that nothing important is omitted, get everything that will have any bearing on any phase of the improvement. Unnecessary information does no harm, but lack of information will mean delay in completing the plans and another trip into the field to secure the missing data.

To fully appreciate the needs of the designers, the field man should familiarize himself with the details of completed plans. The fullest co-operation between field and office forces is necessary. Under no other conditions can the best results be obtained.

ALIGNMENT AND RIGHT OF WAY

Location of Center Line

One of the most difficult features of the field survey is the determination of right-of-way limits and the proper location of the center line. In flat or gently rolling country where the roads follow land lines and where relocations are not necessary, the problem is very much

simplified. In hilly country and on angling roads, the most mature judgment on the part of the chief of party is required. In many such cases the location of the road as shown by the records does not in any way conform to the road as now traveled. The following general instructions should be followed as closely as possible, but many cases not covered by these instructions will be encountered:

a. Get copies of all records in the courthouse relative to the location, establishment, and right-of-way of the road included in the project

b. Run center line before running bench levels.

c. If the established location follows the present road, and the location and alignment are desirable, follow the established location.

d. If the established location does not follow the present road, the choice as to which to follow will depend on a comparison of the two lines as to:

1. Topography.
2. Alignment.
3. Improvements on or along the present road.

Unless there is a decided advantage in favor of the established location, the survey should in general follow the present road. It should be noted that, whichever alignment it is determined that the survey should in general follow, relocations may be made to take advantage of the topographical features, to better the alignment or to make the line conform to existing permanent improvement on or along the road.

e. In cases where the alignment follows land lines, or where a land monument is located on or near the alignment chosen, a diligent effort should be made to find the monuments, and the line should be tied to all such monuments that can be found. If a monument cannot be found, no elaborate land surveys should be made to locate it.

f. Many existing bridges and culverts will not conform to the center line of the road on which they are located. In the case of important permanent structures, the line may be carried so as to conform, but this is not always advisable. The chief of party must use his judgment in this matter, taking into consideration the amount of variation of line necessary, the size and importance of the structure, and all other facts in the case. In many instances it would be poor practice to make such variation in the alignment.

g. Where the records show the right-of-way lines, the notes shall show the position of these right-of-way lines with reference to the center line.

Relocations

Before making relocation surveys, the district engineer or chief of party shall always look up the land owner or tenant and acquaint

him with the intentions of the party. A little consideration thus shown, previous to the survey, may do much to avoid friction with owners of private property.

Relocations may be divided into five classes, namely, relocations to improve:

a. Grades.
b. Alignment.
c. Railway crossings.
d. Stream crossings.
e. Location.

No fixed rule can be set forth under which the selection or rejection of a relocation can be definitely determined upon. The solution of such problems must be left to individual judgment. The location of a highway is its most lasting feature and it is, therefore, imperative that all alignment or location problems receive very careful attention from the most experienced men available.

It will often be found that a relocation will fall in more than one of the above classes, and it also often happens that a relocation which would improve the road in one respect may prove to be detrimental in other respects: i. e., a relocation to avoid steep grades may require the use of alignment not as good as the original. In such cases, recommendations should be made by the district engineer only after careful consideration has been given to the need for the relocation and the advantages and disadvantages of all alternate routes. In making such a study it will often be found that a much better idea of the layout as a whole can be obtained by plotting on the same sheet and in their true relation to each other, the alignment sketches and profiles of the various routes in question. Several sketches of this kind have been prepared in the central office and sample prints will be sent to the district engineers on request.

In the past, much trouble and delay have resulted from unsatisfactory alignment. In many cases, it has been necessary to send the party back for additional relocation surveys before the project plans could be completed. It is seldom that such extra work should be necessary and it is believed that strict observance of the following rules will result in its elimination:

A. Send in alignment sketches of *all projects* showing all proposed relocations.

a. In considering the necessity for relocation surveys the district engineers must take into consideration their past experiences with the general office as well as their own personal judgment. It is well to remember that we are

now making relocations which would probably not have been made a year or two ago.

b. Sketches should be approximately to scale so that a good idea of the layout can be had.

c. Sketches should reach the central office some time before the party completes the survey so that if it is felt that additional surveys should be made it will not be necessary to bring the party back from some other job.

B. In case of doubt as to the feasibility of any location, a survey should always be made.

C. In general, where relocations are surveyed, a survey shall also be made over the old road. The necessity for this will depend upon local conditions. If it is at all likely that a relocation would meet with local opposition, a compete survey must be made over the old road. If, however, all parties concerned agree on a relocation, a survey over the old road would not be necessary. The district engineers must consider each case separately and decide accordingly.

In all cases where relocations sever the connections between secondary roads and the primary road, complete surveys must be made for connections which will properly serve tributary traffic.

In all cases where relocations do not leave the old road over, say, 800 feet, and where a complete survey is not made, the notes shall show the alignment of the old road either by offset ties from the survey center line or by a separate traverse.

D. In running relocation surveys, the chief of party shall set substantial stakes at all points where the center line crosses fences. The center line shall also be tied in to nearby objects, such as prominent trees, buildings, field gates, fence corners, etc. Such stakes and ties are of much value when tracing the course of a line on field examination.

E. In locating a line near a stream or water course, great care must be exercised lest the earthwork on the proposed line encroach on the adjacent stream in such a manner that the latter cannot be properly handled. Unless it is plainly evident that no trouble would occur, the chief of party should never pass over such places without first plotting the cross sections at the critical points and also plotting on the template lines to an assumed grade line, in order to assure himself that the proposed line is feasible. In many cases it will be necessary to locate

the course of a stream or ditch for some distance outside the right-of-way lines; for example, when it appears desirable to make a channel change in connection with bridge work or to prevent a stream from encroaching on the road. The district engineer should become sufficiently familiar with the topography and needs of the road that he can outline such special surveys to the field party early in the survey so that the chief of party may plan his work to better advantage.

F. It is often found desirable for various reasons to shift the center line a few feet after the plans have been prepared. This applies to existing roads as well as relocations. District engineers should keep this in mind while going over a project with a party chief and should instruct him to extend the cross sections beyond the usual limits wherever it appears that such information might be useful.

Intersection Angles

Intersection angles, however small, shall be measured and recorded. All intersection angles shall be measured and recorded. All intersection angles shall be measured by the repetition method.

Horizontal Curves

At all points of intersection where the intersection angle is greater than 2 degrees, horizontal curves shall be run in, and the stationing shall be carried continuously around such curves. In running in curves, the data given in the *Harger & Bonney Highway Engineer's Handbook* shall be followed.

Curves sharper than a 6-degree curve shall not be used except at right-angled turns and in other special cases where sharper curves must be used.

A 6-degree curve is not to be considered as standard for all curves except at right-angled turns. On relocations the degree of curve used may occasionally depend upon the central angle, but in general it is desired to hold to a 4 or 5-degree curve as the maximum where conditions will permit. Under some conditions it might be advisable to use even a flatter curve than 4 or 5 degrees. For example, when following an existing road laid out with curves flatter than those mentioned above, when running a relocation parallel to a railroad track, or when the profile or general location at the curve might be improved by throwing the center line a greater distance in from the *PI*.

When conditions will allow it, a 10-degree curve shall in general be used at right-angled turns. In many cases, buildings, orchards, cemeteries, etc., will necessitate the use of curves sharper than 10 degrees. In such cases the flattest curve possible should be run in."

The admirable construction manual of the State Road Commission of West Virginia may be quoted as follows:

"**SURVEYS AND PLANS—GENERAL**

1. **Introduction:** Modern traffic demands have revolutionized highway construction during the last few years. The advent of motor-driven vehicles, both pleasure and commercial, has made the old highways, with their sharp curves, narrow roadways and poor alignment, inadequate for present-day needs. The luxuries of today are the necessities of tomorrow; hence the highway engineer must not only meet the present-day demands but, as far as practicable, he must anticipate future needs.

Our laws governing permissible speed on the highways are based largely on unimproved roads with bad grades, dangerous curves and short sight distances. The increase in the number of automobiles has made traffic regulation a difficult problem, and in many parts of the country it has become imperative that the permissible speed limit be raised in order to take care of the traffic. Because of this, curves must be eliminated, roadbeds widened and grades reduced, even on improved roads.

It is the duty of the engineer, in locating a section of road, to study changes that future traffic demands may make necessary and to so design the road that these future improvements may be made at minimum cost.

The purpose of these instructions is to call to the attention of both the location and designing engineer, some of the elements that should be considered in locating and designing roads.

2. **Objectives:** The first step to be taken when a section of highway is to be improved is to determine the objectives or the points between which the road is to be constructed. This information is furnished by the commission when it issues the order for a survey.

5. **Reconnaissance:** With the objectives established, it becomes the duty of the survey parties to run the best line possible between these points. Topographical maps have been prepared by the United States Geological Survey, which in mountainous country will be of great assistance in the location of the proposed highway. A careful study of these maps will often show the most practical line between any two objectives and may make unnecessary the running of more than one line. These maps are drawn on a small scale—usually 1 to 62,500—and in very rough country will not show all details of topography. However, they will prove very helpful in making a reconnaissance of the territory.

The location engineer should walk over the entire line and establish control points. These controls are points through which any location between the objectives must pass.

Such a control may be a village, a low gap in a ridge, a stream crossing, a road intersection, a slide, etc. These are controls either because the road must pass through or over them or else must avoid them. With the control points established, it becomes a matter of detail in locating the line. In flat country this is comparatively easy, while in rough, mountainous country it is sometimes very difficult, requiring real ability and careful study.

The grade, alignment, exposure, flood conditions, likelihood of slides and probability of snow drifts must be considered. Seldom will it be found possible in locating a section of road in rough, mountainous country to find a line that will be ideal from every point of view. The location engineer must carefully weigh the relative importance of the various requirements before making a definite decision.

6. **Grades:** The maximum allowable grade, unless specifically excepted, is seven per cent on tangents and less on curves to compensate for curvature. In running any preliminary hand-level line compensation should be taken into account. This compensation should start far enough back on the tangent to permit traffic to slow down in approaching the curve. Unless absolutely unavoidable, grade changes should not be made in horizontal curves. Horizontal curves at summits are to be avoided.

7. **Alignment:** The road should be made as straight as topographical conditions will permit. Unless absolutely necessary, curves sharper than 20 degrees should not be used. A sight distance of at least 300 feet should be provided. Use simple curves. Compound curves of 6 degrees or more whose difference of curvature varies 4 degrees or more are dangerous and should not be used. Reverse curves may be used only on authority of the division engineer.

8. **Exposure:** In high altitudes, where there is likelihood of snow and ice remaining on the road for long periods, the question of exposure should be given careful consideration. To permit the maximum amount of sunlight on the road, southeast, south and southwest exposures are preferred to northwest, north and northeast exposures.

In West Virginia the geological strata in general dip toward the northwest. Water following these seams will keep the roadway in cuts wet on locations having a north or northwest exposure. On the other hand, a southeast exposure is likely to be dry because the subterranean drainage is usually away from the road.

9. **Flood Conditions:** It is often necessary to locate a road through a section of country subject to floods. The location engineer should make investigations to determine the probable elevations of high water and frequency of flood conditions. It is often impracticable to locate a line above extreme high water because of excessive cost. However, the roadway should be above the elevation of those high waters occurring every year or two.

10. **Slides:** The location engineer should thoroughly investigate soil conditions to ascertain the probability of slides. Where impossible to avoid a location subject to slides, it is sometimes preferable to go over the top rather than through the same. Cutting through or into the toe of material subject to slipping nearly always results in starting the hill to moving, which necessitates taking out a very heavy yardage before equilibrium is again obtained.

11. **Snowdrifts:** During the winter season it is often possible for the location engineer to determine where snow drifts are likely to occur. At other times all possible information along this line should be secured from local residents. This information should be used in finding a location as free as possible from the tendency of snow to drift along the roadway.

12. **Hillside Location:** It is often necessary in mountainous country to locate a road from a low elevation to the top of a ridge or other high point. A common fault in locations of this kind is to allow the road to follow the hillside on easy grades for too great a distance, thereby necessitating many sharp curves and costly construction. If the hillside is steep and cut by ravines, it is usually advisable to run the maximum allowable grade and get to the top of the ridge as soon as possible and then follow the ridge to the control point; or to start at the high control point, descending on the maximum grade to the bottom and then follow the bottom land to the next control point.

A ridge road costs very little to construct and the drainage problems are fewer than on a hillside or along a stream bed. However, the adoption of a low line is often justified by the better alignment. Stream changes are often necessary on low lines, but the cost of this work is usually less than hillside work and the road will cost less to maintain. These points should be carefully considered before making a final location.

13. **Hand-Level Lines:** In establishing a line between two control points, it is often necessary to run a hand-level line as follows: The finished grade at the control point is assumed. From this elevation the party stakes out on the ground points on a trial grade which it is thought will fit the topography. A Locke level, level rod and chain

are used. Horizontal measurements are taken and stakes placed in the ground as near as possible to the center line of the proposed road. Allowance must be made for the shortening of the line when the center line is run and for grade compensation on curves. This operation may have to be repeated several times, using different trial grades, before the best line is found. An Abney level is often found useful in running this line. Stadia or Wye levels may be used.

14. **Note-Books:** After the location engineer has definitely decided on his location, it is the duty of the survey party to run in this line and record the necessary notes.

The chief of party sees the topography of the country through which the road is to be built and he must transmit this picture to the draftsmen, who, in many cases, will never have an opportunity to see the ground. Therefore, the field notes should be very clear and complete in every detail. It is not sufficient that the notes be so recorded that a draftsman will understand them; they must be made so clear that it is impossible for them to be misunderstood. All notes should be printed, with explanations given in full.

In general, there will be two note-books, one for transit lines and one for levels and cross sections. The chief of party will print on the fly leaf a description of the road, project number, stations covered in the particular book and names of the survey party. He will also note the numbers of other books used on the same project.

Any relocations run will be indexed, giving the pages and book numbers, if these relocations happen to be in another book. At the beginning of each day's work and at the point where this work starts, the chief of party will make a note of the date, weather conditions, names of party and the time work started. At the end of the day's work a note will be made showing the time work stopped. In keeping these notes, standard conventional signs will be used.

15. **Transit Lines:** After the approximate location has been decided upon, the transit line is started. This may be a traverse line or a center line location, depending upon the topography. If the country is rough, the traverse or preliminary line is usually preferable. A center-line location is to be run where the exact economical location can be determined in the field.

16. **Bench Levels:** After the transit line has been run, the line of bench marks will be established, using the U. S. G. S. datum. These bench marks should be at intervals not greater than 1,000 feet and should be on trees, rocks or other objects that are easily found, but out of the way of construction. The bench marks should be accurately described, numbered and painted.

17. **Cross Sections:** After the line of bench marks has been established, levels and cross sections will be run. The level line will be started by taking readings on the bench mark at the beginning. The elevation of the ground at the stakes will be read and cross sections taken on both sides of the transit line far enough out to permit shifting the line, if desirable. These cross sections will be taken with a hand level on hillside work and with a Wye level on flat ground. As a check, readings will be taken on each of the bench marks previously established. All cross sections on curves will be taken on radial lines and on tangents at right angles to the tangents.

18. **Contours:** If the paper location is likely to vary materially from a preliminary transit line, it is sometimes desirable to locate contours instead of the cross sections. The contour interval of five feet is usually used. The elevation of the ground at the transit line is computed, points on the ground at even contour elevations on each side located and horizontal measurements taken to them. A Locke level, five-foot rod and tape should be used in this work.

The points where the contour lines cross the transit line should be located and the stations recorded. If the ground is such that contours taken at right angles to the transit line will not show the true topography, it may be necessary to run a spur line from the transit line and to locate the contours from that line.

19. **Bridge Locations:** Where structures larger than 'standard' are needed, a detail survey must be made in order that a special design may be prepared. The location of bridges is often a control point on a survey and is, therefore, definitely fixed. The stream must be located on both sides of the center line for a distance sufficient to show its direction.

An accurate profile on the center line should be run and cross sections taken at sufficiently short intervals to permit contours of both banks and the stream bed to be plotted. At least two bench marks easily accessible will be established, one on each side of the stream.

The velocity and direction of the current, elevations of high and low water and required waterway area should be ascertained. Any tendency of the stream to scour or fill should be noted and described fully. The possibility of damage by driftwood or ice jams should be noted. The approximate drainage area of the watershed, together with the character of the country, whether flat, rolling or mountainous, should be given.

A profile should be taken of any highway or railroad bridge over the same stream that is within one-half mile. A profile should also be taken of any nearby constricted section of the stream, particularly

if the stream crossing on the road center line is not representative of the true average area of the stream.

Inquiry should be made as to the foundations of nearby bridges, particularly to determine if piling has been used. If piling appears to be necessary, a note should be made as to where they can be obtained locally.

Materials suitable for the construction of the bridge should be located and described. The location of railroad sidings should be noted, as well as all other information that would be of value to the designing engineer.

A core drill should be used for foundation investigations, the elevations of the several formations passed through being recorded. The drill holes should be carried at least five feet into rock while one hole should be carried twenty feet into the same. A sufficient number of holes must be drilled to show the conditions over the entire area of the foundation.

20. **Final Survey:** A final survey of the project is necessary before the final estimate can be prepared. The original transit line from which the cross sections were taken must be reproduced. This will be a comparatively easy matter if the inspector on the project has preserved the stakes and reference points. If the stakes have been lost it will be necessary to re-run the line. All drainage structures, retaining walls, guard rails and other elements of construction are to be located from the transit line so they can be shown on the final plans. If the contract is a paving project, then, in addition, the surface measurements of the pavement will be needed in order to compute the pavement quantities.

After the transit line is located, cross sections are taken. Elevations at the center line, at both sides of the pavement and at other breaks in the cross sections are to be recorded. At least two readings will be taken on the original ground on each side of the roadbed. If the cross sections taken at the original stations will not show all breakage or projections in the slopes, additional sections or measurements to show this excavation are to be taken. Elevations of all drainage structures will be recorded.

25. **Paper Location:** The method employed in making a paper location in rough country is simliar to that used in running the hand-level line in the field. A trial grade is used and points on this grade are spotted on the topographic detail map by using a pair of dividers. After locating these points, a trial center line is drawn, passing through as many of these points as possible without using objectionable curves.

If the road is to be built in flat, rolling country, the recommenda-

tions of the chief of party will simplify this feature of the design and the location of the center line will be an easy matter.

26. **Profile:** After the center line has been drawn, it is necessary to make a profile of the ground along the center line. Stations on the center line will, in all probability, vary from the stations on the transit line and, for this reason, plus stations on the center line must be scaled in order that the elevation on the center line may be taken at the points where cross sections were taken in the field. It will also be necessary to scale the distance between the center line and the traverse line. These distances are spotted on the cross sections in order to get the elevations of the profile. The profile of the center line is then plotted.

27. **Grade Lines:** After the profile of the ground along the proposed center line has been drawn, the grade line should be established and the elevations of the proposed grades figured for each station. These elevations will be spotted on the cross sections of the ground and the sections of the proposed road will be drawn by using a template. Superelevation and widening of curves must be considered in computing the earth work and should be shown on the sections.

28. **Vertical Curves:** Vertical curves are to be used at all breaks in the grade. The length of these curves is based on the algebraic difference between the intersecting grades and in all cases should be long enough to provide a satisfactory sight distance. In computing the algebraic difference between curves, the grade is considered in the direction of the survey. An ascending grade is plus and a descending grade is minus.

29. **Grade Compensation:** The loss in traction due to curvature on a maximum grade of seven per cent is negligible for curves of ten degrees or flatter. Sharper curves, however, require grade compensation. The amount of this compensation should be 0.075 feet for each degree greater than ten degrees, based on a seven per cent maximum grade. The full compensation should be carried for the entire length of the curve from the *PC* to the *PT*. This compensated grade represents the maximum grade for these curves. This should be reduced if possible.

If future improvements demand the elimination of curves, the grade should be flat enough to permit this change to be made without abandoning any more of the road than absolutely necessary.

30. **Superelevation:** In order to minimize the tendency to skid on curves, superelevation is necessary. No satisfactory general formula is available because of the large number of variables which would have to be considered. A theoretical formula will often give a superelevation

in excess of that which experience has shown to be practicable. Under no condition should it be large enough to cause slow moving vehicles to skid toward the center of the curve. The allowable superelevation also varies with the type of pavement used and the condition of that pavement under varying climatic conditions.

The maximum superelevation should start at the *PC* of the curve and run to the *PT*. For grades of one per cent or greater, the center line grade, as shown on the plans, is to be held, the inside of the pavement being depressed and the outside elevated to provide this superelevation. Where grades of less than one per cent are to be superelevated, it is often necessary to hold the inside grade of the pavement and raise the outside, in order to take care of ditch drainage.

31. **Widening:** To provide for the safe passing of vehicles on curves, it is necessary to widen the road bed. This maximum widening should start at the *PC* and run to the *PT* of the curve. Curves for superelevation and widening, satisfactory for present needs, should be drawn up.

38. **Preliminary Inspection:** After the preliminary earth work is finished and before the grade line and drainage structures are inked, a preliminary inspection of the project shall be made. The object of this inspection is to see that the design fits the ground at all places, to obtain any information which the survey party failed to secure, to check carefully the drainage system as designed, to determine any changes that may be necessary in the alignment, grade or structures, and to check the material information. Full and complete notes of the inspections should be made and entered under a separate heading in one of the survey note books.

39. **Estimates of Quantities and Cost:** Upon the completion of the plans and estimate sheets, an estimate of quantities and cost will be prepared on the standard estimate form. The unit prices for this estimate will be prepared by the division engineer."

A field manual of the Michigan Highway Department was quoted in *Roads and Streets* for February, 1928, under the title, "Qualifications of a Locating Engineer," as follows:

"Every highway engineer should learn all he can of railroad location. The books on this are fairly extensive, while those on highway location are few and are not general enough to cover the problems of various parts of the country. This literature will teach the student the underlying principles, but the actual field work can only be learned by experience. To make a successful locator a man must have a highly developed sense of direction and an exceedingly good memory of geo-

graphical locations. He must not get confused in directions and must always know where he is on the ground. A compass will keep a man on a certain predetermined course, but a sixth sense is necessary to keep properly correlated all of the things seen. He must be a keen observer. This is a very important qualification because all knowledge of a locality depends on this power. He must be a student of physical geography, for upon this depends his ability to familiarize himself with the general features of the topography, such as streams and drainage systems, location of marshes, ridges and divides, stream crossings, etc. He must have a knowledge of the principles of geology, and in Michigan, a thorough knowledge of glacial geology will be of vast benefit.

Above all else, the successful locator must have imagination, as vivid as the child who becomes a sea captain in his mind and brings his ship into port, from the far side of the bath tub, laden to the hatches with the wealth of foreign lands. Without imagination nothing is accomplished, for all things are built in the mind first. The locator must be able to imagine and visualize the road winding over the countryside with the cuts and fills made, the bridges and culverts built, even to the guard rail all nicely painted. If he can do this he can see how the hills lie for desirable alignment and grades. He can see if the stream crossings are practical, and he can compare, by the aid of maps which he has made, the desirable and undesirable physical features of the different routes he has under construction. So much for the natural features with which he has to contend.

There are many other things which he must consider. He must consider the relative cost of various routes, both as to construction and right-of-way. This involves a knowledge and experience on actual highway construction. He must consider the effect the remainder of the system may have on his location; the junction with other trunk-lines and with subsidiary roads; the desirability of going through or around important cities or villages. He must consider existing improvements. When one starts to consider a highway routing, he keeps running from one problem into another until first he knows he has reached the limits of the state. This explains the long projects considered.

Some of this may seem superfluous for a highway engineer's handbook, but it will fire the ambition of men to study all the problems hinted at and find others for themselves; it will make real locators of our chiefs of party instead of mere surveyors. Often instructions as to route are sent out from headquarters office which are designated from a map knowledge, backed by superficial observation, which in the main are correct but which may often be greatly improved in detail. Because a certain line is designated on a map is no reason for a chief

of party to accept it in the "sundown and payday" attitude. He should satisfy himself that it is the best, and if he cannot do that, he should call it to the attention of the engineer of surveys and plans."

SURVEYS

Road surveys in general may be divided into two classes:

1. Reconnaissance surveys.
2. Location surveys.

Reconnaissance surveys are made on both new roads and following old roads. However, the methods used and the information sought differ somewhat. The object of a reconnaissance survey is simply to gather information for use in determining the feasibility or advantages and disadvantages of a road.

The vast majority of road surveys follow existing roads, but in the national forests and the undeveloped sections of some states new surveys are sometimes made.

A cursory examination of various routes and a verbal report are frequently termed a reconnaissance, but according to H. L. Bowlby's article in *Engineering and Contracting*, a proper reconnaissance report conveys a graphic impression of the features of the region and route traversed, and contains the fundamental elements affecting construction, cost and maintenance. The engineer should separate the routes reported upon into natural divisions of similar characteristics, giving distances, grades and controlling points of each. He should describe, classify and approximately estimate the material to be moved, giving averages per mile and total for each section, and furnish an approximate estimate of the cost per mile and total cost of the completed road, giving in detail data necessary for estimate of bridges, culverts, riprap, retaining wall and similar items.

It is seen, therefore, that a reconnaissance survey is principally of an area rather than a line and includes not merely a study of the surface of the ground but conditions under

the ground, the probable traffic on the proposed road and other conditions that may affect utility or cost of the route.

Surveying and Staking Out Roads in Unsettled Country

The general methods used in road surveying in unsettled country are much like those used in railroad surveying, but there are some important differences.

The locating engineer on railway work is usually free to select the route that will give the easiest ascents and descents, and the easiest curves. The highway engineer, on the other hand, may be compelled to follow existing highways with few deviations, for it is often difficult to convince the residents along an old road that they will be better served by a new road located elsewhere.

The railway engineer is much concerned with curves and with tangents, as the pieces of straight line between curves are called. To the highway engineer the matter of curvature is important only when he has to consider the effect of swiftly moving vehicles.

The railway engineer is limited to comparatively low grades, that is, to ascents seldom exceeding a 2 foot rise in a distance of 100 feet, and he is usually limited to ascents that are much less steep than this. The weight of the train that a locomotive can have is limited by the steepness of the steepest grade on the line, and the railway engineer is justified in making long detours or heavy cuts to reduce this maximum grade. On the other hand, the highway engineer is limited to a far less degree.

The railway engineer has to consider the location cost of many structures beside the roadway. Expensive station buildings, overhead crossings, high viaducts, and tunnels are among the structures that a railway engineer must consider. But all these are often of much less importance than the cost of lands for railway terminals and right-of-way. While a railway engineer has to face problems involving elements like these, the highway engineer has equally difficult problems in economics to solve, and they are problems wholly different

from those that the railway engineer must master. The highway engineer must consider the soil upon which his road is to rest. Clay will require a treatment different from sand. He must consider the local supply of materials with which to build the crust that is to uphold the wheels of vehicles. He cannot ordinarily hope to import road materials from any great distance. Rails from Pittsburgh go to Alaska for the railroad engineer; but the highway engineer in Alaska must find suitable material in Alaska. The location of a wagon road in a new country may, indeed, be determined largely by the availability of road building materials. In any event, the survey of a wagon road involves a survey not merely of the surface of the earth, but of the materials under that surface. It involves not a mere reconnaissance to determine a feasible route, but a geological survey of the country for miles on each side, to locate and examine the materials suitable for road surfacing.

We occasionally hear a railway engineer belittling the work that a highway engineer is called upon to do. But, speaking from a somewhat extended experience in both highway and railway work, we are sure that there is little to choose in deciding which engineer requires the greater skill or deeper knowledge. The location and construction of any sort of a way, whether it be a railway or a highway, is a problem in economics which only the ignorant will scoff at as being simple.

Probably the best exposition of the differences between railroad and highway location may be found in a paper by F. M. Lavis printed in *Roads & Streets,* October, 1927, entitled "Economic Theory of Highway Location."

Assuming a knowledge of the general principles of surveying, we may pass to a consideration of how to apply it to road surveying.

The Reconnaissance

Before a careful survey is made with a transit and level, it is

customary for the locating engineer to examine the route, or routes, of the proposed road, using only the roughest of instruments—if any are used at all such as a hand level, a barometer, and a hand compass.

This preliminary study of the route of the road is called a reconnaissance. In making a careful reconnaissance the engineer is greatly helped by having maps of the country, such as county maps, or U. S. Geological Survey maps. The latter are especially valuable, for they show not merely the location of roads, railroads, buildings, etc., but they give contours. The contours on these maps are usually spaced 20 feet apart vertically, and by their aid the engineer can determine, not only the grades of any selected route, but he can calculate any given drainage area and determine approximately the size of a culvert needed to carry the run-off after a storm. Unfortunately, there are large parts of the United States that have not yet been mapped by the U. S. Geological Survey. However, by writing to the director of the U. S. Geological Survey, Washington, D C., a small "key map" of any state can be secured. This key map will show exactly what "quadrangles" have been mapped. The sheets are usually to a scale of practically a mile to the inch. Where the sheets are bought in any considerable number they may be had for 3 cents each.

It is not often that an engineer is called upon to locate any considerable length of road through a country where no roads exist at all, but, for the benefit of those to whom such task is allotted, a few suggestions will be given.

1. Make your reconnaissance cover an *area,* and to not confine it to one or two *lines.* In brief, make a rough map of all the country that can possibly be traversed by a road. Use an odometer for measuring distances, a prismatic compass for determining directions, and an aneroid barometer for ascertaining elevations. Roughly map the courses of all streams, for natural highways usually follow the courses of streams.

2. Having decided on the best general route, hunt up a place where a good, cheap road may be built for a long stretch, and then work both ways from that stretch.

3. It is a common error to reject routes having a short stretch of earth grading, in favor of routes that have many long stretches of moderately costly grading, which, in the total, will prove more expensive.

4. It is a common error to avoid routes having much clearing of trees or brush. To the engineer who is fighting his way through brush and fallen timber, clearing always seems more expensive than it really is. A common bidding price for heavy clearing is $50 an acre, and grubbing of roots may cost as much more per acre. In a strip 10 feet wide and a mile long, there are 1.212+ acres, say 1 1/5 acres. Hence to clear a 10 foot strip will cost $60 a mile, other widths in proportion; and to grub them will cost an equal sum in addition. More will be given as to costs subsequently.

5. It is a common error to stick too closely to trails or existing roads in making a reconnaissance for a new road.

6. In selecting a route for a road, remember that the wild country through which you are going will some day be settled. Indeed, most roads in a new country are built primarily to build up the country by inducing settlers to take possession of it. Bear this always in mind, and select a route that will best serve those who will inhabit the land on both sides of the road.

7. Consider the scenic effects and how to locate the road so as best to disclose the beauties of the country. Many roads in new country are built to reach certain beautiful spots, yet the engineer frequently forgets this fact in locating the road—or, rather, he is so engrossed with his object of reaching the principal beauty spot that he overlooks many others of minor beauty along the route.

8. Avoid crossing large streams, even if to do so adds considerably to the length of the road.

9. In the Rocky Mountains, and other similar regions, the snow melts first from the south sides of the mountains. This insures a longer season of usefulness for a road on the south side than for one on the north side of a hill or mountain.

10. Remember that an earth road in a wooded valley is apt to be a muddy road for a good part of the year. The brush and trees hold the snow and rain water, which causes the ground to become saturated. Due to the gentle slope of a valley, the ground water is slow in draining away. On the other hand, an earth road along hillside can often be located so as to be clear of trees, and, if it goes up and down over successive "hogbacks," it will have sufficient longitudinal drainage to keep dry most of the year. As between a decidedly undulating earth road that is dry, and a level earth road that is muddy, a horse will invariably choose the dry road, for, even with its steep grades, there is less tractive resistance on the dryroad.

The Preliminary Line

Having chosen the general route to be surveyed, a preliminary line is run, using a transit. If it is likely that more than one line will be run, call the first line the *A* line. The second one will be the *B* line, and so on, reserving the letter *L* to designate the final location line.

There are two methods of making a preliminary survey:

1. The method by transit and chain, and Y-level, taking topography or cross sections either with a Y-level or with a hand level.

2. The stadia method, using a transit and stadia rod to measure distances and elevations.

The first method is the one commonly used, but the second method is frequently used to advantage in running preliminary lines for roads through new country. The stadia method passes the advantage of enabling a small party to cover a big section of country in a short time; but it has the disadvantage of requiring much more office work.

The stadia method is so seldom used on road surveys that we shall not describe it. Moreover, with few slight modifications, the taking of topography by the stadia method as described in the above mentioned books on surveying, will also serve far road surveying.

When a road surveying party is organized to run many miles of line most economically, the organization should be similar to that of a railway surveying party, consisting, in fact, of three parties, all under one "chief," but working separately. The three parties are:

1. A transit party.
2. A level party.
3. A topographical party.

In the ordinary practice of road surveying, it is customary for one small party to do, first the transit work, then the profile level work, and then take cross sections or topography.

Transit Party

A large transit party consists of 5 or 6 men, whose duties are as follows:

1. A transitman, who reads angles and bearings, lines in the chainmen, and keeps notes of all bridges, streams, and fences crossed by the transit line, etc.
2. A head chainman, who carries the front end of the chain and a "flag," or range pole.
3. A rear chainman.
4. A "stake artist" who carries and marks station stakes.
5. A back flagman, who holds a rod, or "flag," for back-sights, and carries lunches, coats, etc., for the rest of the party.

In addition to these, there may be 1 to 4 axmen, if the line is run through new and wooded country.

The "stake" artist and back flagman can be dispensed with, if necessary, and the transit party reduced to three men.

Staking Out the Transit Line

As a rule preliminary surveys follow the lines of existing highways. In such cases, unless the traffic on the highway is unusually heavy, the transit line should follow the center of the highway. At a point exactly half way between fence lines, drive a "hub" where the survey is to begin. This is called the zero point of the survey. The "hub" may be a pointed peg about 1½ or 2 inches square and 12 inches long, and should be driven flush with

the ground. In the center of the peg, drive a brad or a surveyor's tack, over which to set the plumbob of the transit. If the ground is packed gravel or other material in which a wooden peg can not be driven, drive a spike into the ground instead. This first "hub," or transit station, is station zero. Accordingly, a lath is marked as shown in Fig. 1a. The lath should preferably be about 2 inches wide and 18 inches long, and plainly lettered, and driven so that the lettering faces the hub. The letter *A* indicates that it is the *A* line; *O*, that it is a transit station. The lath should be 2 feet to the left of the hub, if the hub is in "new country," or where vehicles will not displace it; but if the hub is driven in the center of a traveled road, the lath should be driven on the left side of the road near the fence, and with its letters facing the hub. If the farmers do not object to having their fences marked, but the number of the station, etc., can be crayoned upon the fence.

Red keel, or grease chalk, should be used for making stakes, and the stake artist should be required to print the letters and figures carefully and neatly, making the lines quite heavy. The lettering should start at the top of the stake and progress downward. That part of the stake on which the lettering is to be done should be planed smooth. By attending to these details a workmanlike job is secured, instead of one having an appearance of being carelessly done.

Stakes are driven every 100 feet along the line of the proposed road construction. These hundred foot stakes are called "stations." As above stated, the first station is Sta. O, the next one is Sta. 1, the next is Sta. 2, and so on; so that by multiplying the number of any station by 100, we have the distance in feet from the starting point. Thus, Sta. 56 is 5,600 feet from the starting point.

Any point between two stations is called a "plus." Thus a point exactly half way between Sta. 2 and Sta. 3 is denoted as Sta. 2 plus 50 (station two plus fifty). A point 42.2 beyond Sta. 3 is 3 plus 42.2 (three plus forty-two and two tenths).

In running a transit line across country, laths, like the one

above described, are driven at each 100 foot station, and they are marked serially. These laths, or station stakes, are lined in by the transitman and are driven carefully so that the top of one stake is precisely 100 feet from the top of the last stake.

But in staking out a transit line along the center of a traveled road it would be useless to drive such stakes in the roadway. In such a case, a common method is to drive a wire nail in place of the station stake, the nail being driven flush with the ground. Then a lath may be driven at the left side of the road facing the rail in the center of the road, the lath having the proper station number upon it. It is wise, in such cases, to drive these laths a definite and uniform distance from the nails that mark the stations; for, otherwise, it is often difficult to find the nails subsequently.

Transitman's Notes

A separate transit notebook should be kept for each road surveyed, and the inside cover of each book should state:

1. The name of the county and state in which the road is located.

2. The name of the road, and its number of the roads are to be recorded by serial numbers.

3. The fact that it is a transit book, and the stations included by the survey recorded in the book.

These data are subsequently lettered in ink on the outside cover of the book, when the survey is finished.

On the first page of the book should be recorded the name of the transitman, followed by the names of his party and their respective positions. Assign a number to each man. At the foot of this page record the day of the month and year that the survey was begun, and the date of completion.

It is astonishing how many engineers fail to record these important facts, and leave nothing by which to identify their note books.

On the second page give a list of all abbreviations used, and their meaning.

Leave the third and fourth and fifth pages blank, and, after

the survey is completed, put an index to the contents of the book on these pages.

Begin the notes of the survey on the sixth page, which is the left hand page, and on the opposite page make a sketch showing the necessary details. At the bottom of page 6 record the numbers of each member of the party, whose names and corresponding numbers are given on page 1; also record the day of the month and the year; record the condition of the weather. In like manner at the beginning of each day's work, start a new page with the numbers of the party, the date, etc. At the end of each day's work state the number of stations covered during the day, giving the number of hours actually worked, and statement of hours lost and the reason for the loss.

When, because of holidays or bad weather, no work at all is done, enter the facts and the reasons on a page by itself, in the proper order in the book. By following these directions, the note book becomes also a time book and a diary of progress.

The transitman enters his notes from the bottom of the page up reversing the usual order of writing. He does this so that, as he holds his notebook horizontally and looks forward along the line, the sketch that he makes on the right hand page will show directions as they actually exist. The written notes on the left hand page should come directly opposite the points illustrated on the right hand page; hence the necessity of beginning the written notes at the bottom of the page to accord with the sketch which must begin at the bottom.

The notes on the left hand page are entered in four columns. The first column, headed, Sta., contains the number of each station and each plus.

The second column, headed *I*, contains the intersection angle, obtained by taking a backsight, "plunging" the telescope on its horizontal axis, and measuring the angle between the prolongation of the last course and the forward course. If, after "plunging" the telescope, it is swung to the left, the angle is marked *L* so many degrees and minutes; if swung to the right it is marked *R* so many degrees and minutes.

The third column, headed "Course," contains the true course or bearing of each line with reference to the true meridian that passes through the North Star. The bearing of the first course may be determined by taking an observation on the North Star, or it may be approximated by adding or subtracting the known declination of the needle, or it may even be assumed. But, after the bearing of this first course is recorded, the next course is calculated by adding or subtracting the intersection angle.

The fourth column, headed "Needle," records the reading of the compass needle, which serves as a check upon the angle read by the transit.

The fifth column contains remarks.

Each transit station, or "hub" should be tied in to three *reference points,* by measuring the distance from the hub to the reference point, and by taking the magnetic bearing from the hub to the reference point. If no objects like the corner of a house, a nail in a fence post, or the like, are available, drive a plug flush with the ground and drive a nail or tack in the center of the plug. When a tree is used for a reference point, it is called a *bearing tree.* (*B.T.*) All reference points should be located far enough away from the hub, so that neither the clearing nor the grading will disturb them.

While distances from hubs to reference points are measured to the nearest hundredth of a foot, it is customary to measure the "plus" of any hub to the nearest tenth of a foot only.

When the head chainman reaches a point where the transit line must change its course, he holds the flag pole horizontally and moves it up and down several times as a signal that he wants the transitman to line the pole in carefully for a hub. Then holding the pole plumb he receives "line" and drives a hub, and then holds the pole hub to receive line for the tack. The transitman signals a right or left by waving his right or left arm, until the pole is exactly on line when he waves both arms. The chainman bears down on the flag pole, and its point leaves a dent in the plug into which the tack or nail is driven. While the transitman

is coming forward the chainman takes measurements from the hub to reference points.

After reading the intersection angle, the transitman does not attempt to lay off the angle on the right hand page of his note book, but prolongs the transit line as if there were no deflection angle at all.

Hints for Transitman

The following suggestions will serve to expedite the work:

1. Take alternate backsights with the telescope reversed to balance errors of adjustment of horizontal axis.

2. Test adjustment of plate bubbles and collimation every day.

3. In prolonging a straight line, do so by "double hubbing," or "double centering." That is, plunge the telescope as usual and put the flag pole on line, then swing the telescope on its vertical axis, take backsight and plunge the telescope again and put the flag pole on line. Half way between the two positions of the flagpole will be exactly on line.

4. Read the distance, on the flag pole by means of the stadia wires, if possible, and thus check the chainmen roughly. If this is not done, check the number on each station as you walk forward. It is a common error of chainmen to repeat the number of a station.

5. In walking forward move very rapidly, for the whole party is waiting for you; and, in setting up the transit, endeavor to do so each time with more celerity than before.

6. Either copy the transit notes each night in an office book, or plot them, so that in case of loss of the field book there will be some permanent record of the work done.

7. In going to and from work, always carry your own instrument if you wish to preserve the respect of your party.

Chainmen's Duties

The "Chain" is an engineer's chain tape, 100 feet long, made of a steel ribbon about ¼ inch wide. The old fashioned link chain is no longer used by engineers on road or railroad

surveys. The head chainman calls for "line" from the transitman at each 100 foot station. When the transitman signals O.K., the head chainman drops the flag pole, which he has been holding plumb and exactly at the 100 foot mark on the chain. He then calls out the number of his station, and the rear chainman calls out the number of his station as a check.

The "stake artist" drives the stake (or nail) in the hole made by the point of the flag pole, after marking the stake. The chainmen check the distance, and then move forward. The rear chainman should hang on to the handle, and not let it drag. Otherwise he is apt to let the chainman get too far.

Leveling Party

If the transit line is being run through new country, where it is probable that changes in the alignment will be made after the topography has been secured and studied, it is the best practice to take only the profile levels with a Y-level, leaving the cross-section elevations to be secured by the topographer using a hand level. But if the line follows an existing highway that is not to be abandoned, it is considered good practice by many engineers to take the profile levels and the cross-section levels at the same time, using a Y-level for both, and dispensing with the topographical party.

Profile Leveling

Profile leveling involves simply ascertaining the elevation of the ground at each 100 foot station, and at every other point between where a decided change in the profile slope of the ground occurs.

Backsights and foresights are usually taken to the hundredth of a foot, although some engineers insist on reading the road to the thousandth of a foot. Rodsights should never be taken closer than the nearest tenth of a foot, for it is a useless refinement to secure elevations of the ground closer than the nearest tenth.

A profile leveling party consists of a leveler and one rodman. The elevation of the ground at each station should be marked on the back of the station stake, for the use of the topographical party. It is a good plan, also, to write the elevation of each bench mark on some conspicuous surface near the B.M., or on a stake driven nearby for the purpose. In case of loss of note books the records can then be found in the field book. In case this is not done, the profile levels should be plotted each night on profile paper, and the bench marks should also be recorded on the profile paper.

The leveler should follow the rules already given for transitmen as to recording the name of the road, date of survey, names of party, index to notes, etc.

Hints for Levelers

The following suggestions will assist in securing accuracy and expedition:

1. Plant legs of tripod well apart and firmly.

2. See that the bubble is in the middle after reading the road as well as before, and always read from the same side of the bubble scale.

3. Keep the distance to the *BS* and to the *FS* as nearly equal as possible, and let the sights be not over 300 feet for accurate work with an ordinary level.

5. Have solid *TP's* preferably so marked that they can be found within a few days. Have solid *B.M.'s* located close together, usually about a quarter of a mile apart; and always have a *B.M.* near a proposed bridge or culvert. In running through "new country," locate the *B.M.'s* at least 50 feet right or left of the transit line, so that they will not be disturbed while clearing or grading the road.

6. Insure that the road is held vertical on *B.M.'s* and *TP's* by plumbing it with the vertical hair of the level, also by having the rodman wave the rod back and forth, and taking the lowest reading.

7. Set the level on the line joining the *BS* and *FS*

points, if possible, and have a pair of leveling screws on that line. This will facilitate leveling up and secure more rapid work.

8. Focus always until there is no parallax.

9. Make all the vertical height possible in going up or down hill, even at the expense of unequal lengths of sights.

10. Use a handlevel to determine ground elevations in the bottom of a narrow, deep ravine or gulch, and thus avoid "pegging down" with the Y-level.

11. Check the calculations by adding the columns of *BS* and of *FS* on each page. The difference in the totals should be the exact difference in elevation.

12. Run a line of check levels over the *TP's* and *BS's,* omitting ground readings at stations. A reasonable difference between the original levels and the check levels is 0.1 foot between *B.M.'s* a mile apart; for *B.M.'s* 4 miles apart, 0.2 foot; for *B.M.'s* 9 miles apart, 0.3 foot. According to the law of chances, the probable error varies as the square root of the number of observations, and consequently as the square root of the distance between *B.M.'s*.

Topographical Party

Wherever a new road is located, it is necessary to take the topography on each side of the transit line for a distance of about 200 feet. To do this a party consisting of a topographer and one or two rodmen is usually required. The topographer is equipped with a hand level and a prismatic compass. The rodmen have a 100 foot lineman tape divided into feet and tenths, and a 15 foot rod divided into feet and tenths. In rough countries it is well to have, also, a straight edge with a bubble tube mounted in the center for ascertaining the side slope of the ground.

The duty of the topographer is to locate property lines, nearby structures, like houses, etc., but more especially to locate and sketch in contours 5 feet apart in vertical elevations. He gets his elevations of stations from the marks on the back

at each station stake, and gets his *HI* by reading the rod help on the ground at each station. His rodmen take rectangular offsets at each station, merely using their eyes in determining the right angle, and guess at the probable location of the 5 foot contour. The topographer reads the rod with the hand level, and, with one to two trials, determines the location of the contour. On fairly steep ground, the distance from the station stake to the rod (held on the contour line) is measured with the tape line; but, on comparatively level ground, the distance may be placed. In very steep countries, contours are best located by the straight edge (above referred to) instead of the hand level. The straight edge may be a home made affair with a hand level wired on to it, and it should be graduated into feet and tenths.

The topographer's notes should consist almost entirely of sketches made to a scale of 100 feet to the inch, in a note book cross-ruled with blue lines 0.1 inches apart.

All contours should be sketched in at the time they are taken, trusting nothing to memory. Contours are worse than useless unless accurately determined, for the sole object of taking contours is to enable the engineer to project a better location of the road on the map than is possible on the field. In wooded country a good field location is out of the question entirely. Even in open country a better location can always be made on an accurate contour map than directly on the ground. We have had occasion many times to demonstrate the superiority of a map location of a road over a field location.

Hints for Topographers

1. In recording the names of his party, daily progress, etc., the topographer should follow the instructions previously given for transitmen.

2. Locate all buildings within 100 feet of the transit line by taped measurements, giving their approximate dimensions and character.

3. Locate all fences which indicate property lines, giving magnetic bearings, and the station and plus at which a property line intersects the transit line. If property lines are indefinite, indicate their position as nearly as possible.

4. Secure the names and initials of all abutting property owners and enter them in the note book.

5. Locate all cross-roads and railroads for a distance of 200 feet from the transit line, and secure the elevations of such roads.

6. Locate all highway bridges, giving the clear span and the profile area of the opening. Make a sketch of each bridge, accompanied by notes as to its character, conditions of substructure and superstructure, and the extreme high water (H.W.) and low water (L.W.) elevations. It may be necessary to interview local residents to ascertain water marks. Make an accurate profile across the stream, and determine the longitudinal profile of the stream from 100 feet each way from the bridge. State whether the existing bridge will serve when the new road is built or not.

7. Estimate the approximate area of watersheds from available maps, using U. S. Geological Survey maps wherever obtainable.

8. In following an old road, locate all places where the farmers have private roads which will necessitate ditch crossings. State whether the private road leads to a house, or to a barn, or merely into a field.

9. Locate existing shade trees, curbs, catch basins, paved gutters, etc.

10. Locate all existing culverts, giving character, length and area of water-way. Note whether water appears to have flooded the roadway at culverts. Note whether the culvert will serve when the new road is built. A culvert or bridge that is strong enough for ordinary loads hauled over "dirt roads" may be inadequate to support a 10 ton steam roller. Existing culverts frequently have to be lowered, which is a fact that should be remembered.

11. Locate all quarries where road metal is available, and all suitable gravel pits in the vicinity of the road, and secure samples of the stone and gravel which should be properly labeled for identification. Small canvas bags, such as shot comes in, make convenient receptacles for samples. Samples of field stone should be secured, and a statement made as to its abundance, whether in fences, or piles, or scattered.

12. Locate sources of supply of stone for gutters, telford base, slope wall and culvert paving, etc.

13. Locate the nearest side tracks where materials for road construction may be delivered, giving the name of the railway.

14. Locate places where water can be obtained for use in road building.

15. Locate telephone, telegraph and trolley poles, and give names of companies owning them.

Reconnaissance Surveys in Canada

In making reconnaissance surveys of several counties in Ontario, Canada, the work was rapidly carried on by an engineer and an assistant, using an automobile for conveyance. Following a general consideration of each county in relation to local markets and shipping points, and the distribution of rural population, the more important roads in relation to farm traffic were examined; progress being made at the rate of about 25 miles in a day. Field notes of each road examined included the following:

Local name of the road.

Location, township and distance covered by notes.

Population on road, and nature of farm products.

Population to be served by road, other than residents on the road.

Industries located on road—brick plants, quarries, sand pits, etc.

Class of vehicles using roads.

Alignment of right-of-way and roadbed, and change of

location desirable to improve alignment or for more favorable construction.

Material on surface.

Sub-soil.

Existing cross section—sketch from fence to fence.

Grades and hills, and desirable changes of location to avoid steep hills.

Drainage existing.

Bridges and culverts, their condition and location.

Electric railways on the road, and their location.

Recent work.

Local material available for their section.

Improvement desirable.

Reconnaissance Surveys in Michigan

In securing data for a system of trunk lines in Michigan, L. H. Townsend in *Engineering and Contracting,* states that in all cases where it was possible the highway officials of the county, township or good roads district were requested to submit to us the road or roads, in their respective communities, which they wished to have the trunk line highway follow. Where this was done, and there was but one choice and no reconnaissance was applied for, we generally adopted that road as a portion of the trunk line system. But where they have failed to give a definite choice or there were several contending routes, or where the route chosen by them did not seem feasible to us, a reconnaissance was made.

The use of an auto was considered, but on account of the speed with which it covered the ground and the inaccuracy of the measurements taken, any information gathered would be too general for even a reconnaissance. It was decided therefore to use a wheel or pace traverse and keep a running set of notes of all information gathered.

Equipment and Field Notes

A good box compass, clinometer, tape and camera were

the instruments used; the buggy wheel or pace was employed as the means of determining distances. It was rather a case of being a close observer than in doing accurate instrument work. One had to be on the lookout for such things, as the character of the country traversed, whether it was timber, cut over land, clearing or improved farms; approximate location of buildings, giving kind; condition of road grade, and if improved in any degree—the width, alignment and drainage; kind of soil on roadway, whether sand, clay, loam or swamp (notation being given of the distance from the starting point to the several changes); location, condition and size of ditches, creeks and streams that might serve as outlets for water from the roadway; measurements of culverts and bridges with condition and location, photographing all truss bridges and others that might need to be repaired or rebuilt; bearings of roads traversed with compass, also compass bearings of intersecting railroads, large streams and roads unless at right angles; noting intersection with corporate limits of cities and villages, if possible. The most important features to be noted were the length and grade of the hills gone over on the road in question. The traffic was also noted and divided into three classes, single rigs, double rigs and automobiles. Although this did not even give a fair estimate as to the amount of travel on the road, it nevertheless showed that it was traveled to a greater or less extent and unquestionably had an influence on the decision of the route to be followed. Consideration was also taken of the available road material such as gravel, stone, etc.

The following running notes made by L. H. Belknap, the reconnaissance engineer, shows the method of recording information:

BETWEEN JONESFIELD TOWNSHIP, SAGINAW COUNTY AND WHEELER TOWNSHIP, GRATIOT COUNTY

Of this 5 miles of line traversed about 2½ miles are sand and the balance clay.

Passed 16 teams going to or from market, 3 buggies and one auto. Also passed 20 houses and one church.

The lands adjoining are only partly improved.

There is no doubt but that the 5 miles would become a main traveled road, giving much service to the community, were a good road constructed on this line.

Across Midland County

In the 25 miles of line traversed across this country 19½ miles have a road built on the line and 5½ miles have not. And of this 19½ miles 14 miles are now a main traveled road. But from the location of improved farms the entire road would be traveled were it improved in sandy and rough places and built where there are now no roads.

Of the 25 miles there are 15 miles of sand land and 10 miles of clay adjoining the line. And of this total there are about 11 miles under some improvements, the good clay being in strips three or four miles wide.

There are 54 houses, 2 schoolhouses and 1 church along the road within a distance of not to exceed 60 rods either side of the meridian.

In traversing the line, 12 farm teams were passed going to or from market and 3 autos.

Mapping

In mapping the reconnaissance work we considered it the wiser plan to have these drawings conform as nearly as we could to the working plans for the finished road. By doing this they showed the more essential features, such as profile, alignment and drainage of the road, and were more easily handled by the officials to whom they were submitted.

In this country there were several different roads which could be taken and used as a portion of the trunk line highway. The heavy line shows the one in preference. These maps were drawn to such a scale (1,000 feet to an inch) that ten miles of road could be conveniently placed on a sheet 20 x 36 inches in size. The width of the road was exaggerated in order that

such things as cuts, fills, ditches, etc., occurring within the limits of the road could be shown clearly. All information gathered was placed on, or adjacent to, the plan of the road except the profile, which was shown below.

Cost

The cost of preliminary surveys of 1,200 miles of road was \$6,500.00 or \$5.43 a mile . The cost of surveying 150 miles of very important road was \$7.00 per mile.

Use of the Abney Hand Level in Highway Location

The following is by T. F. Hickerson in *Engineering and Contracting*.

"The Abney hand level is a more useful instrument in road engineering than the ordinary Locke level because with it both a level and incline line of sight may be established. Its usual form consists of a square bronzed sighting tube 5 inches long, a vertical arc having a radius of 1 inch graduated to single degrees with a folding vernier reading to 5 minutes, a scale of grades from 1:1 to 1:10, and a bubble.

"METHOD OF USE.—Since grades are usually expressed as a per cent, that is, the rise or fall per 100 feet of distance, it is necessary to know the relation between degrees and per cent slopes, which should be remembered as being in the ration of 4 to 7. Thus a 7 per cent grade is equivalent to a 7x4/7 = 4 degree grade. The following table gives the degrees and minutes corresponding to per cent grades varying from ½ per cent to 10 per cent.

Per Cent Slope	Degree Slope Deg.	Degree Slope Min.
½	0	17
¾	0	26
1	0	34
1½	0	52
2	1	09
3½	1	26
3	1	43
3½	2	00

Per Cent Slope	Degree Slope Deg.	Min.
4	2	17
4½	2	35
5	2	52
6	3	26
7	4	00
8	4	34
9	5	09
10	5	43

"To Locate Points on Grade.—Suppose A is a known point on grade, and it is required to locate a point D, so that the slope AD shall be on a given per cent grade parallel to the line of sight BC. Set the vernier to read the angle corresponding to the per cent grade and with the instrument held at B in position for sighting in the hand or on a jacob staff, then place a rod alongside AB with the bottom on a level with the point A and place a target opposite B on the rod at the 'height of instrument' above A. When the 'Abney' is swung slightly backwards or forwards until the bubble is in the center (this position being shown by means of a prism which throws a picture of the bubble into the field of view), the line of sight BC will be parallel to the desired grade and it is only necessary to have the rod moved about until this line of sight strikes the target in order to locate points at the bottom of the rod so that they will be on grade. Thus, if the target points C and C' are in the line of sight, the points D and D' are on the required grade. It should be noticed that this method of establishing grade points is independent of distance.

"To Determine the Slope of an Existing Grade.—Choose two points on the grade. With the instrument held above the first point in position for sighting, place a target on the rod at the 'height of instrument' and with the rod held on the second point, move the vernier up or down until the bubble remains in the center and the line of sight strikes the target, then clamp the scale and read the angle. This gives the grade expressed in degrees which if multiplied by 7/4 gives the per cent grade.

"There is another way to find the amount of a slope, as in the case of a steep bank. Place the base of the level tube parallel to the surface, move the vernier until the bubble comes in the center, and read the inner scale which gives the slope directly as 1 to 1, 2 to 1, etc.

"To Determine Cuts or Fills.—A convenient rod for use in connection with the hand level is graduated as follows: Mark the height of eye (same as 'height of instrument') and label it zero (this would be the approximate height of eye if the rod is made adjustable at the bottom so as to be adaptable for persons of different heights), then lay off distances measured in feet and tenths downward from the point zero to perhaps five feet or more, depending upon the height of eyes of the person who is to use the hand level, also lay off similarly from the point zero upwards to say six feet, thus giving a rod about 12 feet long. Mark 'Fill' just above the zero and 'Cut' just below it.

"Assume A and D to be two points on grade and the instrument set to give a line of sight BC parallel to the grade AD. If the rod is held at D' then the rod reading will be the fill $D'E$ also, if the rod is held at D'' the rod reading will be the cut $D''E$.

"To Determine Cross Sections.—Suppose A is a point on the ground at the center of the proposed road, and it is desired to find the cross profile of the ground on both sides of the point A. With the instrument set to read zero and the zero of the rod at the 'height of instrument' (above A) sight on the rod held at all the breaks in the slope of the ground at measured distances from A and the rod readings will give the elevations of the various points above or below A. If the line of sight should run in the ground or be above the top of the rod, move up to the last point or some convenient point and proceed as before, remembering to add to or subtract from the reading for the second position all subsequent readings, in order to refer all elevations to the first position.

"A convenient way to keep notes is to express the data in the form of a fraction, the numerator representing the elevation above or below A and the denominator the distance from A. Thus, the following notes represent certain conditions:

$$\frac{+1.7}{20} \quad \frac{0.0}{9.0} \qquad\qquad \frac{-2.1}{12} \quad \frac{-1.0}{22} \quad \frac{+1.8}{30}$$

"According to the notes, the point B is 12 feet to the right and 2.1 feet below A, the center; also, the point D is 30 feet to the right and 1.3 feet above A.

"TO SET SLOPE STAKES.—Suppose the center fill at A is 2 feet and the road is to be 30 feet wide with banks sloping 1½ (horizontally) to 1 (vertically). It is required to find where the slope of the banks intersects the surface of the ground.

"Set the vernier to read zero and clamp it. Use a rod with a sliding tape on which graduations are marked up and down from O. With the instrument at the height of eye above A, sight on the rod held at a distance of at least 15 feet. The rod readings give the elevations above or below A. The method is to guess at the distance and try the elevation, or vice versa. The point S is correct because the rod reading is 0.0 and the distance is 15 plus $2 \times 3/2 = 18.0$ feet. The stake S shows where the fill begins and it should be labeled thus: $\left\{\begin{array}{l}\text{F (indicating fill)}\\ 18.0\\ 2.0\end{array}\right.$

indicating that it is 2 feet below and 18.0 feet from the center of the finished road.

"DIFFERENTIAL LEVELING.—The 'Abney' when set to read zero can be used just as an ordinary level to determine the difference in elevation of two or more points, in cases where great accuracy is not required. If a rod graduated up and down from the height of eye is used, the notes may be kept as shown in the table.

STATION	+	—
A..............................	....	....
B..............................	....	5.0
C..............................	....	4.2
D..............................	4.0	....
Total	4.0	9.2

Difference = —5.2

"According to the notes, *B* is 5 feet below *A*. *C* is 4.2 feet below *B* and *D* is 4 feet above C, the difference in elevation between *A* and *D* being 5.2, the difference between the sum of the plus and minus readings.

"Adjustment—Set the scale to read zero and raise or lower one end until the bubble remains in the center, then reverse the position of the instrument end for end and if the bubble is out of center the level is not in adjustment. To adjust it, turn the capstan headed screw at the end of the level tube until the bubble comes half way to the center. In order to adjust exactly, several trials are often necessary.

A good way to test the adjustment is to stand on some point *A* and sight on a target held at the 'height of instrument' above another point *B* and note the angle. Then stand at *B* and sight on the target held above *A* and see if the angle is the same (on the other side of zero.

"Adaptability of the Abney Level to Highway Location.

The writer has found the Abney level indispensable in side hill location. It enables one to determine grade points quickly and is a time saver in running preliminary trial lines. As to its accuracy, the readings taken not over 100 feet apart (preferably about every 50 feet) should be within ½ inch of exactness, provided, of course, the instrument is in adjustment and the engineer is careful to keep the 'height of instrument' constant. The errors are compensating and for this reason the Abney, in the majority of cases, will give a preliminary line close enough to be adopted as the final location. The writer has used this level in laying out fully 75 miles of road in hilly and mountainous country.

"Very few highway engineers seem to be familiar with the merits of the Abney as compared with the Locke level. It has all the advantages of the Locke and many additional uses."

Location Surveys

All location surveys consist of:

1. Location of center line of the route.
2. Profile of the center line.
3. Cross section from which to determine quantities of earth work.
4. Full notes as to stream crossings and culverts, cross roads and private ways, soil characteristics and the location of local sources of materials for road construction.

Surveys in unsettled country are similar to railroad surveys. Surveys in thickly settled country which follow in general the existing roads vary widely in thoroughness of execution depending upon the character of the improvement contemplated and the relative cost of construction.

Securing Right of Way

Should the location survey show that new right-of-way must be secured, notes should be made as to the amount of land required and the property owner.

Procedure in securing right-of-way varies greatly in different localities. As a rule new right-of-way may be secured by:

1. Donation.
2. Purchase.
3. Condemnation.

The procedure in each case depends upon local conditions but as a rule it is wise for the engineer to avoid direct negotiations with the land owner except under instructions from the road authorities.

Surveys Following in General Existing Roads

Surveys in settled country, which implies that for the most part roads already exist, are generally made for the purpose of improving old roads but occasionally an entirely new road is laid out. Straightening out old roads with the partial relocation of some sections of the route is a problem frequently encountered.

The type of survey made varies with the type of improvement and the local condition. When a road is to be paved it is much more important that every detail should be carefully worked out than when the work consists mainly of grading or dredging. Earth roads may be located without loss of valuable work already accomplished as in the case of the relocation of a road already paved. Moreover the cost of making elaborate surveys is out of all proportion to the cost of road grading and draining. The proper distribution of public funds frequently demands that a road pass through several stages of development and the unfortunate inefficiency often found on the administration of public road funds makes it necessary to redesign the road at each stage of improvement.

Present practice in making such surveys may be divided roughly into 2 classes:

1. Earth road surveys.
2. Paved road surveys.

Surveys for Earth Roads

Such surveys may be made simply with a view of ditching and draining the roadway and grading a few hills or with the complete grading of the road in view, paving being contemplated at a future date. In the first case a very simple survey will suffice, provided no change in location is contemplated. In the second case a complete and careful survey into the first class.
should be made. As a rule, however, earth road surveys fall

For light grading and ditching work, surveys frequently omit the measurement of angles with an instrument and the location of the center line in the survey.

The distance is chained and the elevation of each 100 foot station or other convenient station is taken with a level and notes as to culverts, cross-roads, private entrances, width between fences, etc., are made. Angles at turns are taken with the intersection of approximate center lines being ranged in by eye with sight poles. On curves the offset to the center of the road are taken from the ranged center line.

In taking levels for such surveys it is the practice of some engineers to enter in a separate column of the profile note book the amount of cut or fill at each station the surveyor estimates will make a level section at each station. When the profile is plotted the elevation of the "average section" is also plotted and is of much assistance in laying the grade lines.

Stakes are usually set near the fence at 100 foot intervals or the station of permanent objects such as telephone poles, fence posts, etc., marked at greater intervals.

In some cases very meager cross sections are taken frequently consisting only of the center elevation and the bottom of existing ditches. Surveys of this type may be made very rapidly (from 1½ to 5 miles per day) and at a very low cost (from $16 to $30 a mile for full work).

Surveys for Paved Roads

The methods used for making complete surveys vary widely in different sections and will be seen. In general, however, they follow the methods recommended by the U. S. Office of Public Roads and Rural Engineering given in the following general instructions:

Transit and Location Survey

1. The transit line should be established following approximately the center of the road. At every hundred feet on this line temporary points are to be established. A spike driven into the road through a piece of red cloth or tape is a station mark that can easily be found after several weeks. The measurement of this line is to be made either with a steel chain or tape, with a degree of accuracy of 1 in 3,000.

2. Wherever it is necessary to make a bend in the transit line, the transit instrument is to be set up at the bend, and the angle of the course ahead with that of the rear course measured, always measuring from the back sight around to the right. The angles are to be measured to the nearest

minute, and where local disturbances do not preclude doing so, magnetic bearings of each course should be observed.

3. Opposite the points established in the road, and on the side far enough removed to be clear of all construction work, stakes are to be driven. These stakes should be about 24 inches long, and driven for a depth of 12 to 15 inches. The stakes are to be numbered, beginning with zero, each hundred feet to be a unit. The offset distance of centre of stake from the station point on the transit line is to be measured and recorded in the notes to the nearest 0.10 foot.

4. At all bends stakes should be set on both sides of the road in a line through the point of deflection and at right angles with the back course. These stakes will be used as reference stakes and should have a small nail driven in the top from which measurements to the nearest 0.01 foot are to be taken to the deflection point in the transit line. Reference stakes should be driven flush with the ground and another stake driven near by for a marker.

5. As a rule, deflection points should be made at even stations or half stations, a half station being designated by the number of the previous station with plus 50.

6. After the location of the transit line as described, offset measurements are to be taken at each station or as much oftener as may be necessary to locate properly the sides of the travelled way and fences or walls alongside the road wherever such exist.

7. Measurements should be taken so as to locate all bridges, culverts and cross drains of whatever description, and the direction of flow through them should be shown by an arrow. The clear opening of all waterways should be indicated.

8. The location of all cross-roads and private entrances should be indicated.

9. Landowners' names should be obtained and dividing fences, where such exist, should be located.

Levels

After the transit and location survey is made the levels are run as follows:

10. Permanent bench marks at either end of the work and at convenient intermediate points are to be established well out of the way of any construction. The number of bench marks should be at least four or five to the mile and as much oftener as convenience may require. Bench marks should be on permanent objects on which a rod can be conveniently held, and located where they can be readily identified on the ground. The roots of trees with low-hanging limbs are not convenient, nor is a point so far back from a line of trees along a road as to shut off all view of the bench mark, except directly opposite it.

11. A line of check levels should be run touching every bench mark, and separate notes kept of these check levels. Elevations should check to 0.10 foot per mile. All readings on bench marks and turning points should be to nearest 0.01 foot.

12. Readings for ground elevations should be to nearest 0.10 foot. Ground elevations are to be taken at the center of the road at each station or 100 feet and as much oftener as may be necessary to show irregularities in the profile or cross section.

13. At each place where a center reading is taken, side readings are to be taken to show accurately the cross section of the road.

14. To take a cross section, first take reading of the rod on the top of the stake at that particular station and a ground reading at same point. Enough readings are to be taken at other points across the line of the road to show the true shape of the banks, gutters and ditches on each side and the road between. The distance of each reading from the transit line is to be recorded as well as the reading itself.

15. Elevations are to be taken of the following points:
   a. The bottom of openings at each end of all culverts, indicating them as east and west or north and south ends.
   b. Bridge floors, tops of abutments and bridge seats.
   c. The entrance and exit ditches on stream bottoms about 25 feet from either end of a culvert or bridge, so as to give the grade of the stream bed near the culvert.
   d. High and low water in streams (estimated).
   e. Water surface of streams as found.

The following extracts from various authors seem of value in this connection:

Alignment and Grades

The location of a road as before suggested is the fundamental consideration in determining its utility to the community. D. H. Ainsworth, a noted railroad engineer, said of railroads: "The location is giving it a constitution. It may be sick, almost unto death, with accidents of construction and management, but with a good constitution it will ultimately recover." The same might also be said of highways.

Essentials of an Ideal Location

In fulfilling this object the essential requirements for roads are as follows:

1. Its direction should be as straight as possible toward the traffic objective or between two or more points in the case of trunk lines. This necessitates the consideration of topography and curvature as well as the needs of each mile of the country through which the road passes.

Grades

Its grades should be as flat as possible, avoiding unnecessary undulations and never exceeding the maximum grade selected for the route.

Cost

Its cost should be the least that will make the route what

it ought to be with respect to the traffic and the wealth of the community.

To fulfill all of these requirements it is easily seen that the shortest line would pass over or through hills and across valleys; the most level line would wind around hills and ascend valleys, the cheapest line would avoid all cuts and fills. It is manifestly impossible to satisfy all of these requirements and the most economical line must necessarily be a compromise between them.

Physiography of Location

To effect the most economic location for a route some knowledge of the laws governing the conformation of the earth's surface is essential.

It is a proverb among French engineers a section of country is either flat or hilly or "a location that is not in flat country is in a mountainous country." That's to say except in perfectly level country it is necessary to consider carefully the topography in order to secure an economic location.

Road locations may then be divided into two great classes:

1. Location in flat country.
2. Location in broken country.

The origin of hills and valleys and their arrangement is a result of natural laws that are discussed in any standard work on geology. In their developments the action of water escaping from higher to lower levels plays a most interesting part and is worthy of close study by the road engineer.

Gillespie states that "Hills being the greatest antagonists and natural enemies of the road maker, he must endeavor to find out their weak points, and to learn where he can best attach and penetrate them, and most easily overcome their opposition to his improvements. Water courses being his guides and chief assistants, he must study their habits and principles of action, and learn what are the causes which produce their seeming vagaries of direction."

Mountains or hills are generally arranged in chains al-

though sometimes grouped together or standing alone. The high points are called peaks, and the depressions between peaks are called gaps or passes. The chains may be composed of several parallel ranges from which branches or spurs may project. Frequently the foot of the ranges merge gradually into a piedmont or hilly section, and the hilly section merges into a flat section, coastal plain or prairie land. Sometimes a gradually sloping table land or elevated plateau exists at the foot of the chain which may be merely level or gradually sloping.

Line of Greatest Slope

The topography of the land, as before stated, has been greatly affected by the action of water escaping to the sea. All flowing water tends to follow a well defined track corresponding to the line of greatest slope.

Effect of Flowing Water on Topography

In descending the slopes of hills and mountains, water has either adopted existing channels, or hollowed out new ones following the lines of greatest slope. The valleys then formed are either at right angles to the ridge when it is horizontal or if inclined, share in the general inclination of the ridge. Secondary ridges are then formed between the streams leaving approximately the direction of the stream. When the secondary ridges of two or more approximately parallel chains intersect a principal valley between the chains is formed. The inclination of this valley varies according to the degree the chains are parallel and the general inclination of the chain. The stream formed between the chains may follow the line of intersection of alternate valleys and ridges jutting out from the chains or where such valleys and ridges are directly opposite each other the principal valley may be alternately wide or contracted.

The heads of streams are in the gaps or passes in the chains being fed in the beginning by water that flows down the slopes of the peaks. The small beginning is augmented

by water from intersecting valleys until a great stream is formed.

A great stream marks the principal valley between the chains. The development of the smaller streams flowing down the smaller valleys is like the branches of a tree, their points of divergence from the trunk and medium size and small branches approaching a right angle in proportion as the ridges of the slopes they flow between approaches a horizontal line.

As the coastal plain or flat country is approached the general adherence to the laws outlined appears less marked, but the same laws still hold true. In some cases the streams wind with great bends, in other places they spread out over a wide area, forming swamps, or the water may have eroded a deep channel between high banks. Also the effect of the current striking and being deflected from alternate points increases the sinuosity of the stream. But it must also be remembered that other conditions of general geology and soils also influence their course and the general topography of the section.

Determining Topography From a Map

In determining topography much may be inferred from a map showing the direction and size of streams by remembering the laws of their formation and the general character of the ridges that must lie between them.

C. S. Moorsfield in Bul. 463 of the U. S. Office of Public Roads and Rural Engineering states that in locating or relocating a public road the prime consideration should be (1) the comfort and convenience of the traveling public which it is intended to accommodate; and (2) the economy of public funds. The first consideration fixes the general location of the road and limits such details of design and layout as affect the safety and comfort of travelers. The second should control the detailed working out of a location to suit the topography or surface layout of the region through which the road

passes, with due regard for such features of the design as affect the cost of construction, of maintenance, and of hauling over the completed road.

The comfort and convenience of travelers require (1) that the road pass conveniently close to the dwelling places of those for whose particular use it is built; (2) that it be free from dangerous curves and grades and sufficiently wide for safe travel; and (3) that the surface be such as to remain reasonably firm and smooth and to become neither very dusty nor very muddy under any combination of weather and traffic conditions. The extent to which any particular road must meet these requirements depends, of course, on the state of public sentiment in the community which pays for the road. But is most communities it is safe to assume that the standards of excellence as regards the accommodation demanded of public roads will be raised rather than lowered. Due foresight, therefore, should be exercised in working out the location and design of a road, so that later improvements, such as reducing grades, increasing the width of the traveled way, or constructing a better surface, can be made without the necessity of making expensive changes in the location or otherwise wasting any considerable part of the work already accomplished.

A few general rules regarding the location and design of public roads may be stated briefly as follows:

1. Avoid sharp curves in the road, because such curves are a menace to traffic. On light grades and level stretches the location should be preferably such that a traveler may see at least 300 to 500 feet ahead from any point on the road, and on steeper grades this distance should be increased if automobile traffic is to be reasonably safe. Where the view is unobstructed and the grade is practically level, country roads of ordinary width may be curved to a radius of only about 200 feet without seriously inconveniencing traffic, but to safeguard against accidents the radii of curves located on grades

should be preferably not less than about 300 or 400 feet, even if the view is perfectly open.

2. Provide ample width for vehicles to pass each other without leaving the traveled way.

3. Bear in mind that if a road ever becomes of any considerable importance, its users probably will demand that all the steeper grades be reduced to the lowest maximum that would conform to the general topography of the region which the road traverses.

4. Avoid all unnecessary distance. Aside from the advantages to traffic of a short route, each mile of additional road involves a considerable extra yearly expense for maintenance, and this alone may warrant the extra expense of shortening the route when the road is constructed, provided that the decrease in distance does not materially increase the steepness of the grades.

5. Regard land lines only in so far as this may be done without decreasing the usefulness of the road or increasing its ultimate cost. The tendency in most rural communities is to locate all new roads along land lines, regardless of the suitability of the route, and this has been responsible for much waste in the past. Not infrequently roads located along land lines have been graded at considerable expense, and abandoned later when the community demanded a more highly improved road with better grades.

6. Give reasonable consideration to the pleasing features of the location. A large part of the travel on most country roads is for pleasure, and the degree of pleasure experienced in driving is largely dependent upon the scenic attractiveness of the road.

7. Plan to avoid the necessity for subsequent changes in location. Such changes nearly always work hardship on some of those who have built homes along the road.

The actual procedure of laying out a road should be controlled very largely by the lay of the land which the road is

to traverse. Where the country is comparatively level, for example, practically the whole problem, aside from proper drainage, may be to determine a reasonable balance between the desire to avoid unnecessary damage to farming land and the purpose to secure a reasonably direct route over good ground.

In mountainous regions, on the other hand, the problem may be to fit the road to the contour of the country, regardless of land lines, cultivated fields, and all other considerations except grade, drainage and line.

In general, the proper location and design of a road involves: (1) determining its controlling points; that is, fixing its general route with reference to certain points which the road must pass through, (2) surveying a route which passes through the controlling points and is otherwise adapted to the lay of the land, (3) a study of the drainage situation, (4) preparing such plans and drawings as are necessary for proper construction and a complete record.

Controlling Points

Such features of the locality as gaps through ridges, exposure to the sun, narrow stream crossings, and suitable points for crossing railroads (preferably by means of overhead bridges or under passes), together with the necessity for connecting up with certain centers of population, usually will serve to fix the location of a road within fairly definite limits. For important roads these controlling points are determined by careful inspection of all possible routes. Between these controlling points the ideal line is straight like a stretched chord bent to the right or left at various points but continually tending to follow a direct line.

Location of New Roads

Seldom does an engineer have an opportunity to locate an entirely new road. The original locators have usually been the cow, the Indian, or the early settler. Such roads as have not developed from paths, trails, and winding wagon tracks,

have been most laid out by land surveyors, who had more regard for convenience in staking out property subdivisions than for the economics of road building.

When an engineer is called upon to make an entirely new road location, he should employ the methods commonly used in railway location, beginning with a reconnaissance, following with preliminary surveys, and ending with a final location. Provided with Lavis' "Railroad Location," Crosby's "Highway Location and Surveying" and with "Searles," any engineer can adopt the methods of railway surveying to road surveying.

Grade Undulations Not Objectionable

The railway engineer when called upon to locate a road is prone to stretch his black string over the profile in a straight line for almost as many "stations" as he is accustomed to do in projecting a railway line. He forgets that the grade undulations that are objectionable in operating long trains of cars moving at high speeds are not at all objectionable in wagon or motor car transportation. Indeed there are many highway authorities who claim that slight undulations of grade are desirable where the land is level, to facilitate longitudinal drainage.

Aside from the unnecessary earthwork usually involved in building long stretches of road on the same grade line, there is a very important objection to doing so where a succession of cuts and fills are made. A cut, or excavation through a hill, is a place where snow lodges in the winter and where it stays longest in the spring. The snow dams up the ditches, and, when it melts, it saturates the subsoil, since it cannot flow away on the surface as readily as it can find a passage through the porous ground. Water will thus find its way underneath the pavement in a cut, even where ample ditches are provided. The authors have often been astonished to note the effect of very shallow cuts in thus causing subgrades to become saturated in the spring of the year.

The road engineer should break up his grade line into short sections if necessary to avoid cuts, provided that by so doing the maximum or ruling grade is not exceeded.

Curvature Not Objectionable

Except where the traffic is to accommodate many rapid moving motor cars, sharp curves and many of them are not particularly objectionable in road building. In brief, it is generally better to swing round even a small projection of land than to cut through it. A railway engineer delights in long tangents, and it is with difficulty that he can persuade himself to introduce frequent curves on a wagon road where a little additional grading will yield a straighter line.

Location in Flat Country

The prime requisite of a location on flat country, the question of controlling points and the general direction of the route having been determined, is to secure adequate drainage. This is usually best accomplished by elevating the center of the roadway above the level of the surrounding country. There is a tendency to place too much emphasis on the amount of excavation in flat country location.

Districts subject to overflow may be avoided or boldly crossed by providing a type of pavement that will not be injured and suitable protection works.

Swamps should generally be crossed in the most direct lines that will approximate the high ground.

Culverts and bridges may sometimes be avoided completely by care in location.

Location in Hilly Country

The question of controlling points and general direction of the road having been determined, location in hilly country is generally a matter of securing the cheapest route not exceeding a given maximum grade, with few intervening undulations of grades and little curvature.

The types of location generally encountered are:

1. Valley.
2. Ridge.
3. Sidehill.
4. Ridge crossings.
5. Hills and foothill crossings.

These may occur on any route whether an old road, or entirely new road or an old road, parts of which are to be relocated. In considering any of them proper attention must be given:

1. Maximum grade.
2. Undulations as affecting quantity of excavation and drainage.
3. Size and number of culverts and bridges.
4. Geology of country affecting the character of subsoil and the type of excavation.
5. Nearness to possible sources of material for improving the roadway surface.
6. Cost of right-of-way.

These and other local conditions affect the cost of the route.

Valley Location

The common problems in valley location are to determine:

1. Whether the route should follow the foothills or the stream bank.
2. The number of stream crossings economical.

As a general rule it is well to keep away from stream banks and to avoid bridges and culverts. Valley locations usually have many culverts, light grades, and moderately straight alignment.

Ridge Location

A ridge location follows the top of a chain of hills, consequently there are few culverts, the excavation on top of the ridge is small, and the grades follow the general inclination of the chain. These advantages are, however, frequently off-

set by the heavy excavation and sharp grades necessary in ascending or descending from the ridge.

Side Hill Location

A sidehill location follows the level contour of the side-hill or to cross these level contours gradually to secure light grades. This type of location is much used where possible Culverts are usually few in number and smaller in size than in valley location and the excavation is hauled only a short distance to make embankments. If the sidehill is much broken or eroded, however, the route may be tortuous or the excavation heavy.

An effort is generally made to place the center line on a sidehill of such slope so that the cut will make the fill. On steep hillsides or in treacherous ground it is sometimes necessary to excavate the entire width of the road from the hillside, to build retaining walls to hold the fill or in extreme cases to use viaducts or tunnels.

Ridge Crossings and Line Developments

In crossing ridges or hills or in approaching gaps in chains, it is often necessary to introduce additional length in the line so that the maximum grade will not be exceeded. This lengthening is called line development.

Hill and Foothill Crossings

In crossing hills and foothills the problem generally arises as to the economy of varying from a straight line. In many cases the distance around the hill is but a little longer than over the hill and by sacrificing straightness, light grades are secured. Or the top of the hill may be cut and the bottom filled.

In crossing foothills, where there are many small valleys and ravines it is usually better to adhere to a straight line cutting the projecting points so that the excavation will make the embankment.

Location and Construction of Highway in Mountain Country

F. W. Harris, in *Engineering News,* states:

"In the far West, the problem is not building a particular section of road for a thousand years, but rather building a passable road and allowing posterity the next thousand years in which to improve the road when improvement is justified. By anticipating the wants of our grandchildren we only place such a heavy burden of taxation upon the present generation that bona fide efforts for road improvement are discouraged.

"All highways are designed for motor-driven vehicles and these are yearly increasing in efficiency. Observations show that light cars are a success on roads full of deep ruts and boulders. The light and so called under-powered cars are often given as one of the reasons for establishing a low rate of grade on highways, when in practice such cars have little trouble in ascending 15 per cent grades even on badly surfaced roads.

"**Maximum Grades.**—Grade is not an object with the heavier type of motor vehicle; suitable surfacing is the most essential requirement. Automobiles of every description travel up 10 and 15 per cent grades in the City of Seattle, Washington. Loaded motor trucks are daily ascending a 12 per cent grade on a country road in the vicinity of Renton, Wash., and this rate of grade is a very common one in the hill country of western Washington.

"Trunkline highways through the mountains located on grades up to 8 per cent will give a much better alignment in nearly every instance than the customary 5 per cent limit now in vogue in this section of the country.

"**Alignment.**—Probably half the automobile accidents are due to curvature, and their prevention must be in good alignment, grades receiving secondary consideration. We cannot make our mountain roads fool-proof, but the careful tourist, unfamiliar with the road, is entitled to a chance to dodge the speed lunatics who drive through the hills at 30 miles per hour.

"Where the *PC* and *PT* are visible through the long chord of the cure, any degree of curve up to 40 degrees is allowable. Curvature in cuts and around projecting bluffs should be kept down to a limit of 30 degrees even if the cost of construction is increased at such points.

"A farmer or teamster would rather pull up a mile of 8 per cent grade on a good alignment than a mile and a half of curves on a 5

per cent grade, with a possible surprise party awaiting him at every turn of the road.

"**Surveys.**—Contours every 5 feet, if taken carefully 100 feet each side of the center line, will make a good map for projecting the highway line, if the preliminary line is in about the right place. Such a map will bear the most careful study, as with the use of broken and adverse grades, tangents of $\frac{1}{2}$ to 1 mile in length can be located in the heart of the mountains.

"All *PI's* should be run out and curves should be offset from tangents. This saves time and results in greater accuracy. As curves seldom exceed 400 feet in length, this is easily done. The levelman in heavily timbered country can obtain levels on the curve stakes with a hand level, if necessary."

Curvature

Curves are a necessary evil as affecting economy of transport and an aesthetic advantage as affecting the appearance of the road. But since the object of a road is generally to improve transportation facilities, curvatures should be eliminated where possible and reduced to a minimum compatible with the justifiable expenditure on the route.

Unfortunately much of the curvature in existing routes is irremediable due to conditions of settlement of the country transversed.

Types of Curves

The curves generally used in road building follow the arc of a circle and may be laid out in the same manner as employed in railroad construction. Other curves following the arc of a parabola or an ellipse are sometimes used and are fully as satisfactory but more difficult to lay out on the ground Curves following no regular arc may also be used to advantage. There is no reason why any curve that fits the conditions of the particular case should not be used.

For vertical curves connecting grades it is necessary to use the parabolic arc due to the ease with which ordinates may be computed.

Maximum Curvature

The degree of sharpness of curves economical for use on roads depends on

1. Safety and speed of travel.
2. Topography of the country.
3. Intensity of settlement of the country.

The last two factors affect materially the cost of eliminating curvature.

Safety and speed of travel is of course a fundamental consideration and in attaining this object it is necessary to consider

1. Sight distance of vehicles approaching or passing each other and the distance within which they may be brought to a safe stop.
2. Permissible speed of vehicles and the elevation of one side of the roadway to increase the maximum speed possible on the road.
3. The size and length of vehicles and teams using the road and the curves suitable for their use.

It is evident that maximum speed conditions are obtained in motor traffic. Maximum size and length of vehicles or equipage may be in either horse or motor traffic.

The minimum radius of curvature recommended by many engineers varies from 75 to 150 feet depending on local conditions.

Sight Distance

Sight distance is the distance an object is visible from a vehicle rounding a curve or nearing the crest of a hill.

Sight Distance Allowed

The sight distance recommended for horizontal curves by various engineers varies from 150 to 500 feet, depending upon general conditions of grade and alignment. On vertical curves a sight distance of from 75 to 300 feet, is recommended, varying with similar conditions. Less sight distance is ordinarily needed on grades than on horizontal curves due to

the general reduction in speed on a hill and the quicker stopping possible through the aid of gravity.

H. E. Bilger, in *Engineering News,* states that for the most rigid types of Illinois roads, as brick and concrete, parabolic vertical curves should always be used when the rate of change from one grade to another is as much as 1 per cent, and for the more resilient types of roads when the rate of change is as much as 2 per cent. Both the safety and the comfort of travel require these vertical curves, though their proper lengths are dependent upon factors that necessarily must be assumed.

It would be only reasonable to assume that in rural territory, automobiles frequently ascend short grades up to 10 per cent at a rate of from 15 to 25 miles per hour. To come from this speed to a full stop, there should be provided at least 150 feet. If it is assumed that on ascending grades two automobiles are approaching one another, each at the rate of, say 20 miles per hour, the vertical curve at the summit should be of such length as to enable the drivers to see one another where they are at least 300 feet apart.

With the eyes of the drivers 5 feet above the road surface no vertical curve is required to meet this condition when the change in the rates of the grades is not more than 6.67 per cent. When this change is 10 per cent, however, the curve should never be less than 200 feet long. Likewise, changes of 13 and 16 per cent would require minimum curves of 292 feet and 360 feet respectively. Practical considerations would commonly suggest the use of vertical curves before they would be required to meet this condition, but nevertheless it is well to have in mind reasonable limits within which ordinary practice should be confined.

Methods of Increasing Length of Line of Sight

The length of the line of sight may be lengthened by

1. Increasing the radius of curvature of horizontal curve or the length of vertical curves.
2. Widening cuts on the side that interferes with the line of sight.

3. Removing obstruction to vision such as vegetation, houses, etc., on the inside of the curves for as great a distance as possible.

At right angle turns mirrors have been used in some cases.

Mechanics of Curves Resistance

When a vehicle is in motion around a curve the two principal forces in action are

1. Centrifugal force acting upon the whole vehicle, along the radius of the curve, tending to cause it to leave the road.
2. Resistance to centrifugal force due to the friction of the wheels on the road surface, acting in a direction opposite to the centrifugal force.

If the centrifugal force is greater than the resistant force the vehicle will skid and leave the road.

Two cases may occur:

1. The speed may be so great that the vehicle is overturned by the force acting about the fulcrum, if the resultant force R falls outside the wheel gauge.
2. The speed may be so great that the centrifugal force exceeds the frictional resistance between the wheels and the roadway. In this case the resultant force within the wheel base and the car skids or slips sideways.

The latter case is more likely to occur than the former which is usually provided for in the design of the vehicle and may greatly increase the danger of overturning.

The centrifugal force C of any body of weight W, expressed in pounds, moving at a speed of V feet per second in a circle of radius R, and the acceleration of gravity is 32.16 feet per second is:

$$C = \frac{WV^2}{32.16\ R}$$

If the body moves at V miles per hour.

$$v = \frac{5280V}{60 \times 60} = 1.47\,V$$

Expressing R in terms of degree of curve, D, $R = \dfrac{5730}{D}$

Substituting these values in the equation we have

$$C = \frac{2.16\,WV^2}{32.16\,R} = \frac{WV^2}{14.85\,R}$$

$$\text{Also } C = \frac{2.16\,WV^2}{32.16 \times \dfrac{5730}{D}} = \frac{2.16\,WV^2D}{184{,}276}$$

Expressing centrifugal force in lb. per ton

$$C = \frac{2.16\,WV^2D \times 2{,}000}{184{,}276\,W} = \frac{2.16\,V^2D}{92.14} = \frac{V^2D}{42.65}$$

The following table gives centrifugal force in lb. per ton at various speeds on a one degree curve.

Speed in miles per hour	Centrifugal force on a 1 degree curve
10	2.335
20	9.339
30	21.013
40	37.357
50	58.370
60	84.053
70	114.405
80	149.427
90	189.119
100	233.480

The centrifugal force on any degree of curve may be obtained by multiplying the centrifugal force on a 1 degree curve by the degree of curve used. Example, the centrifugal force on a 40 degree curve at 30 miles per hour equals $21.013 \times 40 = 840.52$ lb. per ton weight of vehicle.

For the vehicles to overturn it is necessary that the resultant R_2 fall outside the wheel gauge. On a level road this is on the point of occurring when

$$\frac{W}{C} = \frac{\text{height of center of gravity above road}}{\text{half the gauge between the wheels}}$$

The height of the center of gravity varies with different vehicles depending on their construction and the character of the load. The center of gravity of unloaded motor vehicles varies from 1½ feet in some automobiles to 4 feet in some trucks. With some loads the center of gravity may be 6 to 8 feet above the ground. This gauge of vehicles usually varies from 3 feet 8 inches to 5 feet.

With a height of center of gravity of 5 feet and a gauge of 5 feet,

$$\frac{W}{C} = \frac{5}{2.5}$$

or, $C = \frac{1}{2}W$ when the vehicle is on the point of overturning.

A vehicle weighing 4,000 lbs. with a gauge and center of gravity as given will exert a centrifugal force of 2,000 when on the point of overturning. If the vehicle is travelling at a speed of 40 miles per hour and the road is flat the degree of curves on which the vehicles will be on the point of overturning is from the preceding table—

$$\frac{2,000}{37.36} = 53.6 \text{ degrees}$$

The tendency to overturning is, however, offset to a small extent by the action of springs.

Resistance to the horizontal thrust due to centrifugal force is offered by friction of the wheels on the roadway. This frictional resistance on a level road is equal to $W \times$ coefficient of friction, or an inclined, or crowned road to $W \tan \alpha \times$ coefficient of friction.

The coefficient of friction on an inclined or crowned road may be taken as the sum of the coefficients for the forces necessary to push the vehicle up the incline (which equals $W \tan \alpha \div \frac{W}{2000}$) and the coefficient of friction between the material composing the wheel tires and the road surface called K.

Considering only the inclined surface as resisting centrifugal force it is seen that the inclination of the roadway in order to prevent sliding must be such that

$$W \tan \alpha = \frac{WV^2}{gR}$$

or

$$Tan\ \alpha = \frac{V^2}{gR}$$

But since frictional resistance f due to the contact of the materials in the road surface and the wheel tires always exists,

$$W \tan \alpha + f = \frac{WV^2}{gR}$$

at the point of sliding, or

$$Tan\ \alpha + K = \frac{V^2}{gR}$$

when K is the coefficient of friction.

But since

$$\frac{WV^2}{gR} = C = \frac{2.16\ WV^2D}{184{,}276} = \frac{WV^2}{14.85R}$$

$$Tan\ a + \text{coef. of materials} = \frac{2.16V^2D}{184{,}276} = \frac{V^2}{14.85R}$$

Prof. T. R. Agg, Iowa State College, has made numerous determinations of the coefficients of friction between wheel tires and various pavements. The following table gives the coefficients of friction of various materials as given by Trautwine and Masik, based mainly on the experiments of Morin.

	Coefficient of Friction
Wrought iron on wrought iron	.14
Wrought iron on oak	.25
Wrought iron on soft limestone, dressed	.49
Wrought iron on hard limestone, wet	.30
Rubber on macadam, dry	.50
Rubber on macadam, frozen in winter	.033

Bulletin No. 70 of the Iowa Engineering Experiement Station, Ames, Iowa, entitled "Tractive Resistance of Automobiles and Coefficients of Friction of Pneumatic Tires," from which the following table was taken gives an excellent discussion of tire friction with road surface:

SUMMARY OF COEFFICIENT OF FRICTION

Average coefficients of friction between tires and **dry** road surfaces, sliding in the line of travel. Each value average of 40 determinations.

Surface	Four wheels sliding		Two wheels sliding	
	Starting	Uniform	Starting	Uniform
P.C. concrete—2 years old	.77	.74	.89	.81
P.C. concrete—5 years old—greasy	.74	.68	.96	.89
Asphaltic concrete	.85	.80	.87	.79
Bitulithic	.73	.67	.69	.61
Wood block	.84	.79	.82	.75
Brick—monolithic	.88	.84	.91	.82
Brick—sand filled	.86	.82	.87	.79
Brick—asphalt filled	.95	.89	.85	.75
Gravel	.65	.61	.75	.65
Earth	.68	.65	..	..

Average coefficients of friction between tires and **wet** road surfaces, sliding in the line of travel. Each value average of 40 determinations.

Surface	Four wheels sliding		Two wheels sliding	
	Starting	Uniform	Starting	Uniform
P.C. concrete—2 years old	.75	.71	.96	.85
P.C. concrete—5 years old—greasy	.82	.76	.64	.54
Asphalt concrete	.86	.82	.86	.82
Bitulithic	.72	.67	.73	.72
Wood block	.73	.48	.81	.60
Brick—monolithic	.65	.60	.60	.54
Brick—sand filled	.66	.60	.62	.43
Brick—asphalt filled	.71	.65	.81	.75
Gravel	.63	.57	.79	.68
Earth	.59	.52	..	..

It is therefore seen that a definite relation exists between the speed of vehicles, the inclination or crown of the road surface on curves, and the materials composing the wheel tires and the pavement.

As an example, let us assume a brick road to be designed for a given safe speed the outside edges of curves being elevated to compensate for the curvature. This elevation is generally called superelevation. If the curve is on a grade it is readily seen there is a great possibility that the estimated speed may be exceeded and consequently a curve on a grade should be superelevated to provide for the probable speed at that point. Let:

V = speed in miles per hour.

$$15 = D, \text{ degree of curve} = \frac{5730}{R}$$

$$1/12 \text{ (1 in. to ft.)} = tan\ \alpha = 0.0833$$

$0.75 = K$ coefficient of rubber on dry brick

Then substituting

$$0.0833 + 0.75 = \frac{V^2}{14.85 \times 369.6}$$

$$V^2 = 0.8333 \times 14.85 \times 369.6 = 4{,}570$$

$$V = 67.5 \text{ ft. per sec. or 68 miles per hour}$$

But at this speed the vehicle is on the point of overturning and it is therefore not a safe speed.

It is almost universal practice in computing superelevation for curves to neglect the effect of frictional resistance between the tires and the roadway surface and consider only the inclination of the roadway as providing for centrifugal force considering K, or the resistance of material, as a factor of safety. Since the coefficient of frictional resistance between the wheel tires and the road varies from about 1/30 to ⅞ and the coefficient of resistance due to inclination or superelevation varies from 1/24 (½ inch to foot) to 1/12 (1 inch to foot), a factor of safety of about 2 is provided for the most extreme case.

It is also the general practice to widen the pavement on curves, the additional width given depending on local conditions.

Superelevation for Curves in California

In determining what superelevation is advisable 3 elements of the layout are given consideration in *Engineering Record*—namely, degree of curvature, grade and length of curve. The controlling factor, however, is the degree of curve. In other words, it is unnecessary to superelevate the large-radius easy curve where the speed of vehicles is limited by law to 20 or 30 miles per hour, inasmuch as the average driver almost invariably reduces the speed on curves, particularly where the view ahead is obstructed. It is therefore the sharp curve, introducing considerable centrifugal throw, which is considered as warranting particular attention as to superelevation.

For a given width of pavement established as suitable for the volume of traffic involved, certain proper speeds on specific radius curves can be assumed, the commission believes, and the following relation, based on the unit amount of superelevation necessary to eliminate the outward throw, can be used to determine the unknown:

$$V = \sqrt{\frac{32.2 \times R \times e}{w}}$$

in which R equals radius of curve in feet, e equals superelevation in feet, w equals width of roadway in feet, and V equals velocity in miles per hour. Considerably higher speeds than the theoretical ones given in the table are safe and comfortable for passenger machines on account of the margin against overturning inherent in their construction. The formula gives speed at which centrifugal force is perfectly balanced. In general, the practice is to superelevate all curves having a radius of 300 feet or less, with special consideration for curves of greater radius on speed gradients and of considerable length. After numerous experiments with superelevation

ranging from ½ to 1 inch per foot, a standard for all curves has been adopted at ¾ inch per foot. It has been found that the theoretically correct speeds for a ¾ inch per foot superelevation on a 15 foot roadway are as follows for curves of different radii:

Radius feet	Speed, miles per hour
300	16 to 18
250	15 to 16
200	13 to 14
150	11 to 12
100	10

This table has been based on the finding that almost invariably the speed of motor vehicles varies directly with the radius of the curvature, and if this assumption is true, it has been pointed out that theoretically, as well as practically, the adoption of a constant rate of superelevation is warranted within the limited radii under consideration.

In constructing concrete pavements the method of transition from crowned to superelevated sections is indicated in the accompanying drawing. This layout has been adopted after trials of numerous methods of joining such sections and an observation of how traffic is affected. It is recommended that different templates be used so that smooth curves of a gradually changing section are obtained. Whether the work is done by hand templates or by machine tamper, the setting of the header boards is of utmost importance, and they should be carefully checked before "striking off" by either method.

Grades

Grades, or an inclined longitudinal profile, are introduced to facilitate straight alignment and to reduce the cost of construction.

We may now discuss grades from the standpoint of:

(a) Maximum grades.

(b) Minimum grades.

(c) Intermediate grades.
(d) Balancing earthwork.
(e) Details of elevation, drainage, etc.

Maximum Grades

The determination of the economic ruling grade for any route must be based on varied factors all affecting cost. In general these are

(1) Character tonnage of traffic.
(2) Topography of country.
(3) Type of pavement.
(4) Direction of greatest traffic tonnage.

It is readily seen therefore that the elevation of a maximum grade is a separate problem for each route in itself.

Also, grades may be considered with respect to

(1) Maximum single grade.
(2) Total rise and fall, or the average grade.

The first affects the maximum weight of a single truck that may be transported over the road and the second affects but little the weight of single loads or the tonnage of traffic but materially affects the cost of construction.

Some engineers seek to derive the maximum economic grade from the average grade by selecting as a maximum the average of the grades on the route. This method is fallacious and leads to absurd results under some conditions. But if it is assumed that intermediate grades will not be changed and the average of the grades *closely approximating the maximum* is taken, the result will be approximately correct. In short, the maximum economic grade is that which reduces the ratio of the cost of transport to the cost of construction and maintenance to a minimum.

The maximum desirable grade varies also with the type of pavement, some material being so slippery as to be dangerous on steep grades.

Maximum grades in Europe are as follows:

	Mountainous Per cent	Hilly Per cent	Level Per cent
England (Holyrod road by Telford) usually	3.3	3½	
Germany	4-8	3½-6	2½-5
Simplon Pass road over Alps, Italian side	4½		
Swiss side	6		

The maximum grades in France and Austria are determined by type of road and consequently the tonnage transported.

	1st class (National)	2nd class (Departmental)	3rd class
France	3	4	6
Austria	4.7	5-6	
	1,000 ft. of 8.33	8.33 by permission	

	Mountainous percent	Hilly percent	Level percent
U. S. Aid roads	6-8	4-6	2-3
State Aid roads	5-8	3-5	3
County roads	6-8	3-6	4
Neighborhood roads	8-10	4-6	4

C. H. Moorehead, in Bulletin 463 of the U. S. Office of Public Roads and Rural Engineering, states that according to the best current practice, where the road is or is expected to become of sufficient importance to warrant a highly improved surface, the maximum grade usually is fixed with reference to this feature about as follows:

	Per cent
Coastal plain and prairie regions	2 to 3
Average rolling country	4 to 6
Hilly or mountainous regions	6 to 8

Economy in Grading

W. G. Harger states in *Engineering News* that grading is the most permanent feature in road improvement, and for that reason there should be no false economy in this part of the expenditure. In establishing the profile no economy should be attempted by exceeding the ruling grades; there is no object, however, in reducing a natural grade of, say 4 per cent to 3 per cent, provided the adopted ruling grade is 5 per cent. The

economy of profile design is limited to the intermediate grades, and these grades should follow the natural profile as closely as possible.

The selection of the cross-section affords a chance for economy. A wide cross-section with deep ditches requires more grading than a narrower cross-section with shallow ditches. A commonly used cross-section is one 32 feet between ditches, which are 18 to 24 inches below crown grade. For most places a 26 foot width with 12 to 14 inch ditches is satisfactory.

Minimum Grades

Gillespie states that on macadam and earth roads French engineers formerly used a minimum grade of 0.8 per cent and English engineers, 1.5 per cent. American engineers use a minimum grade on such roads of from 0.5 to 1 per cent. The former is satisfactory for broken stone roads and the latter desirable for earth roads.

Intermediate Grades

The intermediate grades are those grades of less inclination than the maximum but greater than minimum grades. It is readily seen that the more nearly they approach a level or the minimum average grade between controlling points, the closer the ideal grade is approached. These grades are controlled by the limiting conditions of the profile, such as balancing cut and fill, the approaches to bridges, intersecting roads, the elevation of highwater marks, railroad crossings, the elevation of abutting property, etc.

There are two general types of intermediate grades

(1) Long straight grades.

(2) Undulating or curved grades.

Long straight grades are desirable in that the average grade of the road and the total rise and fall is materially reduced thereby, and the number of culverts and drains is reduced. If the intermediate grades are less than 3 per cent,

the road may, as has been stated, be traveled with as little inconvenience as a level road. Ditches on less than a 4 per cent grade usually do not require paving. The use of long grades, however, may increase the length of ditch grades, but such ditches are generally at the foot of fills.

The greatest objection to long grades is the increased excavation necessary to construct them. This, however, is frequently over estimated and should not be given very great weight on roads intended for heavy traffic.

Undulating grades follow more nearly the contour of the ground thus reducing the quantity of excavation. By using curves instead of straight lines in establishing the grade line, it is possible to follow approximately the surface of the ground at all points. Undulating grades are very satisfactory for earth roads that have not received a pavement and consequently may be regarded without destroying work already accomplished.

For motor traffic it is possible in some cases to design a system of undulations that the vehicle will coast down one grade and ascend another without the application of power. But where the undulations are such that a continual shifting of gears in ascending grades and application of brakes in descending is necessary the undulations are a disadvantage to traffic.

Balancing Earthwork

Grades should be such that the excavation will make the embankment and where this object is accomplished the grades are said to be balanced.

Balancing earth work may be

(a) Longitudinal, necessitating transportation along the road.

(b) Transverse, the excavation at the connection making the embankment.

The second case is an ideal condition seldom attained for a great length of road except in an ideal side hill location, or in flat country. With a given average side slope a formula

may be derived by which the elevation of the center of the road will be such that this object is attained.

But on very steep ground the road must be made chiefly in excavation or retaining walls constructed.

Similarly the elevation of the roadway in flat country may be such that the ditch excavation will make the embankment.

The following is given by A. H. Moorefield in Bulletin 463 of the U. S. Office of Public Roads and Rural Engineering:

"In fitting the grade line to the ground surface and balancing cuts and fills it should be borne in mind that earth, after being thoroughly compacted, will occupy less space in an embankment or fill than in its original position. The customary allowance for shrinkage and waste in road work are:

	Per cent
For heavy cuts and fills	10 to 15
For average grading	15 to 20
For light grading	20 to 30
For very light grading and considerable sod	30 to 40

"Solid rock will expand from one-third to one-half of its original volume when taken from a cut or excavation and placed in a embankment. But the spaces between the particles of stone should be filled with earth as the stone is being placed in the embankment. If this is done, no allowance should be made for the increase in volume when balancing cuts and fills."

H. E. Bilger states in *Engineering News* that in establishing the general vertical alignment of the highway, there must be carefully considered the construction cost, the serviceability of the road and the practicability of economic maintenance. These three factors will assume varying degrees of importance, dependent largely upon the development of the country contiguous to the road improvement.

The proper alignment for any road is so closely related to such local conditions as topographic features, available funds, etc., that general recommendations might be wholly a misfit when applied to a particular case. It can be safely said, however, that grades should be kept reasonably consistent and closely in harmony with the general topography of the neigh-

boring country, but aside from this there is little justification for expenses incurred in order to obtain grades lower than some 3 or 4 per cent.

To design highway improvements according to a limiting grade fixed for a geographical area even as large as 15,000 square miles is not warranted either by the nature of or by any factors of the highway problem. The whole matter is more of a local issue as regards both the factors of construction and the use of the roads, but in order to make the most out of a given combination of conditions, a broad experience in road building is required.

The Most Essential Element in Surface Drainage

The particular feature of a large percentage of the Illinois roadwork commanding attention is the necessity for positive surface drainage of the roadbed by elevating it above the level of the adjacent fields. In order to maintain satisfactorily a road surface in practically level country on other than a sandy soil it is generally absolutely necessary to forestall capillarity by elevating the roadbed.

It is probably true that on more than one-half of the mileage of the roads in the state, the traveled way is lower than the general elevation of the adjacent fields, and in a large percentage of these cases the practicable gradient of the side ditches is not sufficient to carry off surface water. This condition is due to the simple fact that formerly highway construction consisted chiefly of fencing off a right-of-way across the prairie with attention to the matter of surface drainage.

In connection with tilling the land for agricultural purposes, the under-drainage of the road has been given more consideration than the surface drainage. It has not been fully appreciated that underground drains are primarily for the removal of underground water and that for the removal of surface water these drains cannot be depended upon as more than a 20 per cent substitute for complete surface drainage.

APPENDIX A

Forms and Instructions

In Pennsylvania, where a distinct office in the state highway department is provided to function in all matters of location and of right-of-way, the following forms have been developed and made of regular satisfactory use:

Form No. 468.* (Proposal of Dist. and Div. Engrs.)

LOCATION

PROPOSED RELOCATION OF HIGHWAY

District No. 2-1-0 Bradford-Sullivan County

Route or Appl. No. 17 Sec. 6 between Stations 724-61.9 and 988-61.9

Old Road Present Line				Proposed Relocation			
Length:							
29124 feet				21393 feet			
Degree of Curves above 6°:							
120 °	30 '	in length		16 °	750'	in length	
19 °	400 '	"	"	16 °	1335'	"	"
10 °	800 '	"	"	10 °	2500'	"	"
8 °	900 '	"	"	6 °	500'	"	"
Grades above 3%:							
3.08 %	650	feet		3 to 4 %	1000	feet	
4 to 5 %	2970	"		4 - 5 %	4603	"	
5.08 %	530	"		5 - 6 %	2100	"	
8 to 9 %	550	"		6 - 7 %	2550	"	
9.6 %	210	"		7 - 8 %	2595	"	
%		"		%		"	

*Filled in for a specific case.

Bridges over Marsh Creek stream_____' span_____'
clear 22 ' span 5 ' clear
__________ stream_____' span_____'
clear_____' span_____' clear
__________ stream_____' span_____'
clear_____' span_____' clear

Railroad Crossings and Tracks proposed relocation will eliminate grade crossings on present Route station 740, 758, 831 and 918.

Property Damages and Similar Considerations practically all of proposed relocation is through wooded, pasture and meadow land, value about $35 to $40 per acre. 25 acres necessary to roadway, building to be moved in Dushore Boro. Damage about $10,000.00 to be cared for by Dushore Borough.

Abnormal Maintenance Involved Will be main road south to Eaglesmere, summer resort. Snow condition will be encountered on proposed line.

Scenic and Similar Considerations: Good view from Summit on proposed line. No views worthy of mention on old location.

View Obstructions or other Danger Points: Structure to be moved in Dushore Boro. No other danger points. The proposed line leaving Dushore Boro will eliminate two right angle turns in narrow built up section. Will also connect with direct route into Dushore from the south as recently proposed.

(Use back of sheet or insert pages when more space than provided is needed).

COST OF CONSTRUCTION

Present Unit

	Quantities	Prices	Cost
Excavation	27500	$2.00	55,000.00
Pavement	58250	3.25	189,312.50
Pipe - All Kinds			8,000.00
Drainage - Including Bridges			10,000.00
Plus eliminating 4 R.R. Crossings			140,000.00
COST --			$402,312.50

Proposed Unit

	Quantities	Prices	Cost
Excavation	47000	$2.00	94,000.00
Pavement	43000	3.40	146,200.00
Pipe - All Kinds			6,500.00
Drainage - Including Bridges			8,000.00
COST --			$254,700.00

Unusual Traffic Conditions Involved Will be main route, north and south to Eaglesmere summer resort.

Present Traffic -- Summer
Passenger Cars 500 Trucks 30

Probable Future Traffic -- 5 yrs.
Passenger Cars 600 Trucks 60

Give Material Prices and Haul where possible --

Cement	$2.80 Bbl.	Cement	$ 2.80
Sand	2.70 ton	Sand	2.70
Stone	3.00 ton	Sand	3.00
Haul	1 3-4 miles	Haul	2 1-2 miles

Remarks as to Construction Difficulties, etc. About 30% of excavation on proposed relocation would be classified as rock, however it is sort of a solid shale. No other difficulties would be encountered with possible exception of water supply. This phase of the work could be eliminated by relay system.

Essential Reasons Why Relocation is Desirable Affords a more direct route, as well as a saving in distance of 7731 over the present route, and is the shortest and most feasible line that could be secured between Laddsburg & Dushore. County Commissioners of Sullivan & Bradford Counties have stated that they have no objections to this location. Dushore Boro has a population of about 800 (See Smull's). New Albany Boro 315. Saving in distance will effect all towns north and south of Dushore.

Recommendations In view of the distance saved as well as the operating cost and grade crossings avoided, I would recommend that the proposed relocation as submitted be adopted.

W. E. Bailey
District Engineer.

3-25-25
Date.

REMARKS -

I recommend that this relocation be approved.

J. S. Ritchey 3-26-1925
Division Engineer.

NOTE - This report must be accompanied by a carefully prepared sketch map giving salient information on topography, population, alternate Routes or locations, bridges, distances, etc.

3-26-1925
Date.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS
Estimate of 1940 Traffic

Application No.__________, Route No.______,

Boro.
__________________Twp., ______________County

Location of road, towns connected, etc.

Character of territory served (agricultural, mining, manufacturing), etc.

An estimate of 1920 population of the area served is________persons, as follows:

County	Township or Borough	Population 1920	Population 1910

Percent Area Served	Population Served

Variation, 1910-1920: ______percent increase, decrease.

Estimate of 1940 population of this area________ ________persons.

Estimate of 1924 M. V. Registration______M.V's. per 1000 persons; or____________M.V's.

Estimate of 1940 M. V. Registration______M.V's. per 1000 persons; or____________M.V's.

Ratio of traffic to registration (1924)____________ ____________per 1000

Annual daily average traffic (1924) based on___ ______________________________, is_________trucks, __________passenger cars, Total__________M.V's.

Estimate of 1940 annual daily average traffic by formula:

$$\frac{R\ (1940) \times T\ (1924)}{R\ (1924)} = T\ (1940)$$

	Present (1924)	Future (1940)
District Engineer's estimate		
Headquarters dependent forecast		
Independent headquarters estimate and forecast		

Note: Average Daily Winter, 70 percent; Maximum Summer 187 percent of Annual Daily Average Traffic.

Date:
From:
To:

DEPARTMENT OF HIGHWAYS
Intradepartmental Correspondence
Harrisburg

Form No. 705 March 30, 1925.

Subject: Relocation R-1., S-6, Bradford and Sullivan Counties, between stations 724 and 989 (Dushore and Laddisburg).

From: W. W. Crosby, O. R. 202.
To: Mr. W. H. Connell.

Attached is blue print (showing the present and proposed locations) and Form 468 (giving comparisons between the two locations) as submitted by District Engineer Bailey.

Route No. 17 is a primary state highway route which connects Laporte, in Sullivan County, with Towanda, in Bradford County, and forms a link of the state system which extends from the Susquehanna Trail at Muncy, in Lycoming County, in a northerly direction via Eaglesmere, Dushore, Towanda and Athens, to Waverly, New York, at which latter place it forms a connection with an important east and west route (in New York State) between Buffalo and New York City. The particular portion of Route No. 17 under consideration is situated between the Borough of Dushore, in Sullivan County, and the settlement of Laddisburg, in Bradford County, and is located in the Townships of Cherry and Albany. The contemplated improvement involves approximately 5½ miles of the present road location. Either of the locations will form a part of the primary north and south route to the summer resort at Eaglesmere.

Several alternate locations (intermediate between the two locations shown on the print) have previously been given a considerable amount of relocation study, with the ultimate intention of obtaining a location which would not only be very direct but which would also provide satisfactory alignment and grades at reasonable construction and operation costs. Unfortunately, however, none of such lines considered would apparently satisfy the requirements. The possibility of following along fairly close to the old original Route No. 17 was also given consideration but later dismissed after the facts had been obtained, which conclusively proved the impracticability of this location because of excessively severe grades.

Either of the locations shown on the attached print will be in conformity with the requirements of the existing Legislative Act establishing this route.

An exceptionally good and appealing view will be offered to the users of the highway where the proposed relocation crosses the summit of a rather lofty ridge. The scenic and similar considerations along the present route location are practically unworthy of note.

The proposed location will avoid, for through traffic, at least, four railroad grade crossings of the Lehigh Valley Railway which exist on the present location. These crossings are rather dangerous because of the limited sight distances offered and on account of the severe grades and excessive curvature which prevail adjacent to at least two of the crossings.

The character of the country traversed by the relocation is mostly wooded, pasture, and meadow land. Approximately one-half of a mile of the new location lies in the Borough of Dushore (population about 800), and the other end of the location is at Laddisburg, which has a population of about fifty. Between the termini of the two locations there are about fifteen dwellings (outside of Dushore Borough) along the present route and but three along the proposed relocation.

The length of the present route is 29,124 feet or 7,731 feet more than the length of the relocation (21,393 feet), which is an appreciable saving (25 per cent) in favor of the latter. The maximum grade on the present road is 9.6 per cent which extends for a length of 210 feet. In addition, there are 550 feet of grades between 8 per cent and 9 per cent. On the proposed location the maximum garde will not exceed 8 per cent. The grades, however, on this line are somewhat more severe, there being a total of about 2600 feet of grades between 7 per cent and 8 per cent.

The proposed line, in Dushore Borough, will eliminate two right angle turns in a narrow and built up section and will also form a direct connection with a route into this borough from the south, as has recently been proposed. The alignment along the relocation is a vast improvement over that along the present route, the maximum degree of curvature being sixteen degrees on the former as against a maximum of nineteen degrees on the latter (exclusive of the two right angle intersections). The character of the topography in this locality is of a rough, broken and rugged nature, which physical characteristics more or less limit, or at least restrict, ideal alignment possibilities.

It is estimated that the cost of construction on the present location, exclusive of the costs involved in the elimination of the four grade crossings, would be $262,313. Including the latter costs, however, the costs of construction on the present route would be about $402,313 or $147,613 more than the estimated costs via relocation ($254,700).

The present daily traffic is reported as 500 passenger cars and 30 trucks. The probable future daily traffic is estimated as 600 passenger

cars and 60 trucks. Predicated on the latter amount of traffic the economic formulae of this department shows the following annual operation costs:

	PRESENT ROUTE	PROPOSED RELOCATION
Trucks	$ 44,103	$ 34,783
Passenger Cars............	115,622	84,930
Total	$159,725	$119,713

or an annual saving of about $40,000 in favor of the relocation.

The value of the land traversed by the relocation is about $35 or $40 per acre, I am informed. The amount of such land as would be required for right-of-way purposes would be approximately twenty-five acres. The land damages, therefore, would amount to about $1000. Construction on the relocation would necessitate the moving or razing of a building in Dushore Borough. However, the resultant damages, about $10,000, will be taken care of by Dushore Borough. For the purposes of comparison on this point it may be assumed that if the present location were followed no land damages would be involved, though there would be considerable damage to property or buildings, which latter, however, cannot be satisfactorily estimated now.

No abnormal maintenance conditions would be encountered along either of the locations. Possibly snow conditions may be of a slightly more troublesome nature along the relocation. About 30 per cent of the excavation required on the proposed line would be classified as being of a solid shaley formation; which, however, would not materially hamper construction operations. No other construction difficulties would be encountered on either location with the possible exception of water supply requirements on the relocation. Apparently this difficulty of the work could be overcome by some relay system.

I would, therefore, recommend that the proposed relocation, as shown in red on the attached print, be approved because of:

A saving of 7,731 feet of distance.

A saving of about $148,000 of construction costs (including the costs involved in railway grade crossing eliminations).

A saving of approximately $40,000 of annual operation costs.

The elimination, for through traffic, of four grade crossings of the Lehigh Valley Railroad.

It affords the shortest and most feasible direct primary route between Dushore and Laddisburg.

It offers better lines for traffic, the bulk of which latter will be from without the locality.

The scenic considerations are decidedly in favor of the relocation.

W. W. CROSBY, Location Engineer.

Form No. 468 (R. 7-11-28)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS

Location or Proposed Relocation of Highway

Division No. ______ ______________ County ______________ Township or Borough
Route No. ______
Section No. ______ Location is between stations ______________ and ______________
Appl. No. ______ Between (nearest towns) ______________ and ______________
If an application, how financed? ______________________

	Present Line	Proposed Relocation
Length:	______ feet	______ feet
Degree of curves above 6°: (list each separately - using back of sheet, or an additional sheet, if necessary)	___°______' in length ___°______' in length ___°______' in length ___°______' in length	___°______' in length ___°______' in length ___°______' in length ___°______' in length
Grades above 3%: (list each separately - using back of sheet, or an additional sheet, if necessary)	___°______' in length ___°______' in length ___°______' in length ___°______' in length ___°______' in length ___°______' in length	___°______' in length ___°______' in length ___°______' in length ___°______' in length ___°______' in length ___°______' in length
Bridges required:	____' span ____' clear*____ ____' span ____' clear*____ ____' span ____' clear*____	____' span ____' clear*____ ____' span ____' clear*____ ____' span ____' clear*____

*In this space state who is responsible for financing of bridge, i.e. state, county, etc.

	Present Line	Proposed Relocation
Number of dwellings adjacent to road:	______ houses ______ churches ______ schools	______ houses ______ churches ______ schools
Character of land traversed:	______________	______________
Land damages:	______ acres @ $ ______ an acre	______ acres @ $ ______ an acre
Damages to buildings:	$ ______ for ______ bldgs.	$ ______ for ______ bldgs.

**Railroad and trolley crossings:

	Present Line	Proposed Relocation
No. of grade crossings:	____of____tracks of____R.R.	____of____tracks of____ R.R.
No. of highway under-passes:	____of____tracks of____R.R.	____of____tracks of____ R.R.
No. of highway over-heads:	____of____tracks of____R.R.	____of____tracks of____ R.R.

**Is Public Service Commission action required? __________ __________
**Can any of the crossings be eliminated? __________ __________
**If any complications are involved or if there is a possibility of eliminating any existing crossing, such facts should be stated fully on the reverse side of this sheet.

Abnormal maintenance involved: ______________ ______________

Scenic consideration: ______________ ______________

Historic features: ______________ ______________

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Cost of Construction

	Present Line			Proposed Relocation		
	Quantities	Unit Prices	Cost	Quantities	Unit Prices	Cost
Excavation						
Borrow						
Pavement						
Pipes and drainage						
Bridges						
R. R. grade separation costs						

Unusual traffic conditions involved: ______________________

Present average daily traffic: __________ Passenger cars __________ Trucks
Probable future daily traffic: __________ Passenger cars __________ Trucks

Remarks as to construction difficulties, etc.:

____

(present line) (is)
Essential reasons why (relocation) (is not) desirable: ______________________

____

Opinions of county commissioners, local authorities and property owners affected:

____

Recommendations: ______________________

____

______________ Date

______________ Division Engineer

NOTE: This report must be accompanied by a carefully prepared sketch map giving salient information on topography, alternate routes or locations, distances, stations, etc. Use backs of sheets or insert additional pages when spaces provided on this form are insufficient.

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Summary of Economics

(The following information is to be filled in by the Central Office and not by district offices)

(increased)
Present line is (decreased) by ____________ feet of distance due to relocation

(Present line)
(Relocation) represents a saving of $ ____________ of estimated construction costs

(Present line)
(Relocation) represents an annual saving of $ ____________ in operation costs

(present line) (relocation)
Damages are $ ____________ less on (relocation) than on (present line)

Relocation avoids (____________ grade crossings)
(____________ highway underpasses)
(____________ highway overhead crossings)

and eliminates (____________ grade crossings)
(____________ highway underpasses)
(____________ highway overhead crossings)

Maximum gradients are changed from ________%, ________ feet in length on the present line to ________%, ________ feet in length on the relocation

Present line has ________ curves ranging in value from ____________° to ____________°, whereas relocation has ____________ curves between ____________° and ____________°

(Present line) (relocation)
(Relocation) serves ____________ more dwellings than (present line)

(present line)
Scenic considerations are better on (relocation)

Annual operation costs:

	Present	Proposed
Passenger cars	$	$
Trucks	______	______
Total	$	$

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS
Harrisburg

Subject: Alignment. C-1122

ALL DIVISION ENGINEERS
AND DISTRICT ENGINEERS:

The following principles underlying the establishment of the center line on construction or ultimate right-of-way plans are to be used in preparing all plans:

I—Directness and Straightness of Center Lines

Directness of routes between termini is to be sought particularly on through routes. Directness in this case implies straightness, but does not compel tangents in alignment if their use results in excessive degree of curvature or indirectness in profile.

Acts creating state highway routes name termini and intermediate points on each route. Legal opinion has been given that the Secretary of Highways in improving the routes between termini may select such location as will, in his judgment, give the best results from points of view of safety and convenience, of improving grades, or of saving expense to the state in construction and maintenance. If necessary to achieve these ends, intermediate points on the route may be by-passed by the new location, providing the state constructs and maintains spurs between the points by-passed and the relocated route.

Directness is, therefore, the first step in fixing the alignment. Indirectness may be justified by:

A. Topography.
B. The importance of intermediate points.
C. Developments that have taken place along the old highway and have more or less fixed its alignment as a road to be constructed and maintained without regard to the importance of the straightness of line between termini.

Unless indirectness can thus be accounted for, the possibilities of improving the directness of the route as a whole, or in sections between acceptable points of control should be investigated, and attempts made to relocate any portion of the route, the present location of which section may seem well off the direct line between termini, and, therefore, questionable as to final establishment. This scheme may be employed between intermediate control points and sections.

II—Tangents

Excessive tangent locations are not regarded as necessary or desirable. Where tangents in either the horizontal or vertical plan aid

in securing directness of line, and convenience to both rtaffic and adjacent property, they should be sought and established. Where they do not so justify themselves, curvature should be used.

III—Curves

A. There Are Three Main Objections to Curvature:

1. Curves require more work of calculation, surveying and inspection in their planning and in their actual construction, but this objection must be disregarded by the forces of this department.
2. Curves are objectionable when they obscure vision of traffic to the point of danger. This object is met by the departmental standards for providing clear vision on both vertical and horizontal curves.
3. Curves are objectionable if, by their sharpness, they make unduly difficult or dangerous the operation of traffic at reasonable speeds. This difficulty in horizontal curves may be overcome by adjusting the cross-section of the highway, that is, by super-elevation.

B. Super-elevation.

Theoretically, all curves shall be super-elevated. Practically, it is necessary to establish a maximum radius, below which super-elevation shall be provided.

Present department standards call for the super-elevation and widening of all curves having a radius of 600 feet or less (which practice will be continued) and **super-elevation only** from 600 to 1000 feet. In the future, all curves having radii between 600 feet and 2000 feet and a total length of curvature on center line of more than 200 feet shall be super-elevated, but not widened. Exceptions to these rules may be made in built-up sections.

C. Broken Back Curves.

There has been a tendency to introduce short tangents between two curves in the same direction, which should be discontinued, except in cases where property developments or bridge locations require this. Two curves in the same direction in a horizontal plane should be separated by a tangent of not less than 600 feet unless the clear view along this tangent is interrupted by the profile. In the vertical plane, the intermediate tangent should be not less than 50 feet.

The foregoing applies to both the center line of construction and the center line of the ultimate right-of-way.

Normally, the ultimate right-of-way will be symmetrical about the

center line, but cases of unsymmetrical development may be necessary and will be treated throughout as special cases.

Ordinarily, the center lines of the ultimate right-of-way and the improved roadway should coincide. Reference in this connection should be made to Circular C-923, dated January 19, 1925.

W. H. CONNELL,
Engineering Executive and Acting Secretary of Highways.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS

C-923

Harrisburg

Subject: Ultimate right-of-way surveys and plans. (Supplanting all previous instructions concerning surveys and plans for final location and ultimate width of right-of-way on state highway routes).

ALL DIVISION ENGINEERS
AND DISTRICT ENGINEERS:

The following instructions become effective at once. They take the place of any instructions heretofore given on this subject in so far as they may conflict with or affect such prior instructions. In doubtful cases it will be the responsibility of the district engineer to present the particular situation and secure a decision from this office that will relieve the doubt and clear up the point satisfactorily.

GENERAL

Ultimate rights-of-way, in order to be legally recorded and established, are required by law to be described by their center lines. The description of this center line is similar to the description of a line bounding a tract of land. Hence a careful selection and accurate description of the point of beginning and the point of ending, with equally definite description of convenient intermediate points, is important, and, in fact, fundamental. The description must be concise but explicit so that different persons at different times can be expected to find readily on the ground the original points referred to in the written description.

Wherever practicable the point of beginning in the description should be a point in a borough, a township, a city, or a county line, which line has been legally established and described in the public

records of the state or of a subdivision thereof. If the distance of this point of beginning in such a line can be determined and stated as a definite measurement from an established and recognized monument in the line, or from a recorded corner or angle in the line, or similarly referenced by a measurement along the line in which the point lies to another point in that line about whose position there could be no question, then the point of beginning is well established.

If such an establishment as above is not practicable, it may be practicable to establish the point of beginning, in the sub-division line referred to, by reference to a corner or boundary line of private property adjacent, provided the description of the private property referred to is properly recorded in the public records of the locality. In cases where the above establishment of the point of beginning is not practicable it may be established by determining its reference to the intersection of the sub-division line referred to (if the point of beginning shall lie in such a one) by a recorded property line or by the center line of the original roadway being included in the taking of the ultimate right-of-way for the state highway in question.

The same remarks as above apply to intermediate points on the final center line and to the point of ending of the latter.

The Act of Assembly, authorizing the establishment of ultimate widths for state highways, makes no discrimination as to the section of a route that traverses a borough road or street. Surveys and plans will therefore be made for the section of any state highway through the boroughs just as is required outside of them.

Advantage cannot be taken by a right-of-way establishment itself to relocate an existing highway. While perhaps the greater width of the ultimate rights-of-way taken would, if skillfully adjusted, permit some minor revisions of the old roadway center line, a true relocation of the present road must be treated as a relocation matter. If, therefore, a relocation, involving an abandonment of the present right-of-way and the taking of a new right-of-way for the highway, is contemplated, the establishment of the ultimate right-of-way on the relocation must be deferred until the relocation shall have been determined.

Legal counsel has advised that the establishment of a final right-of-way under the Act, and as being discussed, when formally completed serves to abandon, on the part of the state, the old right-of-way not included in the final right-of-way filed and, consequently, any rights or duties of this department over the portion of the highway abandoned. Until provision shall hereafter be made by law for this department to retain its control over the existing road pending the reconstruction of the road on the new location, it seems therefore, imperative to defer such relocations of the rights-of-way, proposed

primarily to protect a contemplated new right-of-way against encroachment.* Unless, therefore, reconstruction on the new right-of-way is to be recommended contemporaneously for the old highway, the establishment of final rights-of-way on relocations will not be begun until further advices are issued by this office. (*Provision made by Act 1925).

Surveys

Before actually starting the surveys in the field, it will be profitable for the district engineer to go over, with the chief of survey party assigned to the ultimate right-of-way survey on any route, the plans on file for this route. These plans may be simply the old Sproul survey plan and profile or they may include also later construction plans. In any event, office examination of these plans will generally reveal angles in the older center lines which may now be advantageously modified or avoided in this right-of-way establishment. Again improvement of the center line for the ultimate right-of-way may seem to be possible by keeping it to one side or the other of the old center line and at the same time no greater—if not actually less—damages to abutting property incurred. Further, by keeping the widening of the road away from such property as railroad right-of-way—where the effects of any intrusion now might be far reaching and costly—and widening in the other direction which of course means shifting the right-of-way center line laterally from the center line of the older narrower right-of-way, it may be readily possible to avoid many difficulties. Equally the suggested examination of the old plans, preliminary to field work on the new surveys, may suggest reasons for adherence to the old center lines at certain points. In this way a certain control for the survey party may first be set up in the office to the great advantage of actual work thereafter in the field and drafting room.

It would be convenient if the survey line, the center line of the old road, and the center line of the final right-of-way could coincide. Sometimes they can and should, but many times no two of the three can or should be identical. The center line of the old road is often indefinite in its location and more or less susceptible of variance, and many times it ought to be straightened or adjusted. In this adjustment of the old road's center line it is frequently difficult to determine the revision exactly until after the survey line shall have been run. Even in the case of an improved state highway the greater width now being contemplated for the final rights-of-way puts a different light on some of the problems that were supposed to be solved when the existing improvement was made, so that some opportunity for

further or future improvement would be thrown away if now the center line of the ultimate right-of-way should be forced to coincide with the center line of the now improved roadway.

Again, while the center line of the old road, or the center line of the existing improvement, or even the center line of a proposed improvement of comparatively narrow width (say, for instance, not to exceed a total distance of 30 feet or 15 feet each side of the center line) might properly lie in one position relative to a cemetery, a paralleling railroad, or even a substantial dwelling or factory, the center line of 100 foot right-of-way would probably have to lie in another position relative to such adjoining consideration. It would not be practicable, therefore, in such cases to make the center line of the ultimate right-of-way and the existing center line coincide. On the other hand, if proper foresight is had, the survey line might coincide with the center line of the proposed ultimate right-of-way, though it would vary from the existing center line or perhaps a previous survey line. Further, in some cases the center line of the final right-of-way with its considerably greater ultimate width will vary from the previous center or survey lines of the roadway when the avoidance of unnecessary and excessive property damages may be taken into consideration.

The selection of the best center line for the ultimate right-of-way is a matter in which considerable judgment is called for and where good judgment will result very advantageously. Similarly, where it shall be practicable to survey the line which will finally be fixed as the center line of the ultimate right-of-way the rest of the work will be facilitated considerably and some more or less laborious calculations with their inevitable chances of error, avoided.

Too slavish adherence to a survey line will, however, produce unsatisfactory final right-of-way lines whose defects will be of far more moment than any possible saving in survey and office work.

If it is deemed advisable to make any changes in the alignment of a road, already improved under filed plans, such changes of alignment are to be made by the ultimate right-of-way plans only if they shall include in the ultimate right-of-way being so fixed all of the improved pavement and at least 10 feet outside of the latter. Changes of alignment greater than can be made within this limit shall first be considered under the procedure for relocations and shall not be taken up and proposed under ultimate right-of-way procedure.

Where an improved road has been laid on either side of a center line as sometimes happens where a road parallels a trolley line the ultimate right-of-way center line would perhaps normally follow the original center line of the old road, but as will be seen by the foregoing,

it will not necessarily do so. Your judgment is supposed to be exercised in such cases.

Where the ultimate right-of-way being fixed conflicts with the right-of-way of a railroad company, or might take away some of the land of cemetery companies, the location of the center line becomes a matter of judgment as to whether or not it is worth while to persist in the conflict. The state can undoubtedly secure the right-of-way it needs for a state highway, but it is entirely possible that the public interest will be as well served by avoiding the conflict with such semi-public interests and also avoiding probably excessive expenditures of public funds.

Accuracy of surveys is essential. Inaccurate surveys and plans are worse than valueless. They discredit the department.

If the survey for right-of-way plan is made before an improved surface has been laid, the tangents, *PC's* and *PT's* should be carefully preserved by a selection of the most permanent references secureable. References to telephone ploes, fence timbers, etc., or of little value on an ultimate right-of-way plan filed for permanent reference during a long period in the future. References to substantial trees might be of more value. References to durable foundations of buildings would be of greater value, particularly if the buildings were sufficiently described and a reference to the record of the property on which they stand is given. The deeds of the property are generally recorded in the county offices.

The present locations of some of the state highway routes present long continuous compound curves on their center lines. It probably would not be often advisable to attempt to fit the center line of the final right-of-way exactly to such a present center line, and, if the final center line should closely approach the present center line for any reasons, it could be run on the ground as a series of short courses and distances approaching the existing curve. Such a procedure would frequently be entirely satisfactory. On the other hand where the present center line would be a number of short tangents connected by short curves and the final center line would probably best be made by a fewer number of longer tangents connecting longer curves, such a survey line could be run directly in the first place,

Where the deflection angle at the intersection of two tangents is not over five degrees there is no need for running a curve in the ultimate right-of-way center line. Nor is it necessary with even a greater angle to run in and establish a curve in the center line provided the proper curve to fit the conditions would not carry an external distance of over five feet.

It will always be possible to establish the final center line on paper in the offices no matter what the details of the survey line for it have been in the field, and the work of calculating the final line from different survey lines is, in consideration of the benefits of proper correction for the final center line, hardly to be estimated. Too much quibbling over the exact location of the survey line is unnecessary. If it can be run so that good judgment as regards the center line of the final right-of-way will dictate that the latter shall coincide with the survey line, all well and good; otherwise it probably will be best to run the survey line (1) as a center line of the existing road improvement, or (2) as the center line of the proposed road improvement, or (3) as the center line of the existing road, and then determine and calculate in the office the final center line for the ultimate right-of-way from the data so secured. (See also third paragraph under Plans.)

The true bearings of tangents must be determined at the beginning and ending of each survey and must be checked at intermediate points of the survey—at least once every four or five miles.

Culture must be taken for not less than 75 feet each side of the survey line. Details of the ground plans of buildings need not be obtained except for those buildings through which the side lines of the ultimate right-of-way will pass. All buildings within the survey limits should be noted on the plan and the character of their construction such as "frame," "brick," and "stone." Note all property lines and names of owners, fences, parallel and adjacent to the road, bridges, walls, monuments, historical markers and old milestones. Note trees four inches or more in diameter, particularly those near and along right-of-way line or sides of the old road. Locate cross and intersecting roads, railroads with their right-of-way lines, streams with names, trolley poles and tracks, telegraph and telephone poles and edges of the existing roadway. Locate accurately county, township and similar lines crossed.

Plans

Plans will be made on standard 22″x36″ sheets of tracing cloth, with scale of 50 feet equal one inch. Show two sections on each sheet, whenever possible, with sufficient overlapping to establish connection between sections, but without unnecessary waste.

A neat appearance for the plans is important. All letters and figures must be carefully and plainly made and a uniformity displayed. which probably can best be accomplished by having all tracings for a complete plan made by one competent person.

The center line of the ultimate right-of-way must be in black ink

and heavy enough to stand out conspicuously when the prints are made from the tracings. The relative position of the tangents of the center line of the ultimate right-of-way to the tangents of either the center line or the side lines of an improved roadway, where one exists, shall be shown on the plans by offsets (to the nearest one-tenth of a foot) and marked where most conveniently shown. On unimproved roadways the relation of the final right-of-way tangents to existing center line or side line tangents of the present right-of-way, as nearly as they may be determinable, shall be marked by offsets (to the nearest tenth of a foot, if practicable or if not then by figures to the nearest half foot).

Where the intersection angle is not over five degrees the center line of the ultimate right-of-way will be shown on the plans and described as tangents with a point of intersection and deflection, no curves being run in or used. In cases of rights-of-way establishments on unimproved routes or routes improved with other than concrete, brick or block pavements, curves in the center line will not be run in or used for a final right-of-way establishment where the external to the curve would be five feet or less. In such cases tangents only will be shown.

The ultimate right-of-way lines (sides) will be placed on the tracings in pencil only in every case, unless or until specific instructions to do otherwise shall be received.

The plans should show all fences, walls, hedges, streams with names, bridges, buildings (without details of ground plan, except in cases where lines pass through the buildings or where a building is wholly within the proposed right-of-way) and trees (without giving size or names, except in individual cases worthy of special note). Use the word "orchard" or "grove" or similar designation to indicate such groups of trees within their limits and avoid the necessity for showing the individual trees under such circumstances.

The edges of an improved roadway and the sides of an unimproved traveled roadway should be shown without confusion. Ruled lines for the former and free hand dotted lines for the latter would probably suffice in most cases. Show all township lines, county lines and the plus thereto. Place names of townships, boroughs, towns and villages on the plans. Note accurately the stations and plus of *PC*, *PI*, and *OPT*. Curve data must in all cases be placed on the plans and include the stations of the *PC*, of the *PI*, and of the *PT*, the deflection angle, degree of curve, radius of curve, length of curve, and tangent lengths. This data should be clearly placed on the plan between lines drawn radially to the *PC* and the *PT* for each curve.

True meridian courses of tangents and the reference points with ties must be clearly shown. The course of tangent lines must be

placed on the plan close to the point of intersection or close to and just beyond the point of tangent of a curve and also at the end of each section of the plan.

On long tangents the course may be written once in the middle of the sheet on the tangent line if the latter shall be longer than the section across the sheet.

Show all tangent lengths on the plans, that is, the length from the *PT* (or *PI* if no curve is used) to the following *PC* (or *PI*), and place this distance at the beginning of the tangent to which it applies so as to bring it close to the course shown (as above) for the particular tangent length in question.

To avoid an indefinite number of highway route stationings all over the state, it has been decided to retain, at least as a basis, the old Sproul survey stationings and thus have but one system of stationings over the state highway system. There will, therefore, be unavoidable inequalities and adjustments in the stationing of the state highway routes as improvements of them are made. These inequalities will be shown on the plans, and the preferable form of showing them is "station........ back equals station........ ahead." Care must be exercised to avoid overlooking the inequalities in the computation of tangent lengths, and they must be shown on the plans plainly wherever they occur. These inequalities will be adjusted in the tangents and preferably marked and shown at the beginning of each tangent where they occur, that is, immediately after the *PT* of the preceding curve.

The side lines of the final right-of-way recommended will be put on these plans in pencil unless otherwise specifically authorized by this office and along this pencil line at convenient places and twice on each section (once on each side), that is, four times on each standard tracing, place the words "eighty foot right-of-way line" using, of course, instead of the word "eighty" whatever total width of right-of-way is being recommended.

Sections of state highway routes in different counties must be shown on separate plans as the plans for each county have to be filed in the respective county seats.

Don'ts

Do not show top and bottom lines of slope on plans.

Do not show cross section of right-of-way.

Do not show calculations of true meridian. The words "true Bearings" will be sufficient and should be placed once on each sheet of the plans.

Do not show on plans the date of making survey.

Do not show center line in any other color than black.

Do not show reference of points to purely temporary objects.

Do not show "00 seconds" on bearings if there are no seconds in the bearing.

Do not make out any title sheet.

Do not fail to check all the data given—preferably with the original field notes—and do not permit arithmetical mistakes to occur and show up on the tracings. There is no excuse for such mistakes occuring on plans sent to this office by a district engineer.

Some plans have been sent in with offsets varying from one foot to four feet in the center line. Evidently a complete misunderstanding of the requirements of the center line was had in that case and it is hoped that these instructions will relieve that situation for the future. It is, of course, possible that an offset may have to occur in the center line under certain conditions, but such an incident would be most abnormal and the avoidance of an offset in the center line should be had whenever possible.

All ultimate right-of-way work must be carefully, accurately and neatly done both in the field and in the office, and the plans must be most carefully checked in every particular before being forwarded to Harrisburg. While appearance of the plans reflects the spirit and ability of the department, the real value of the plans is in their presentation of hard and cold data and facts. Styles of lettering may change, but the future user of these plans will always appreciate and commend the accuracy of them.

Hereafter address all plans, correspondence, etc., pertaining to right-of-way matters to this office "Attention: Col. W. W. Crosby, Location Engineer," and in the letter of transmittal state precisely, clearly and in sufficient detail the reasons for your decision as to location of the center line of the ultimate right-of-way and as to the width recommended for the latter. In that letter may be made any statements you think desirable concerning the extension of slope toes beyond the proposed ultimate right-of-way side lines.

W. W. CROSBY, Location Engineer.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS

C-1438

Harrisburg

Subject: Engineering Policies Governing* Highway Construction.
ALL DIVISION ENGINEERS:

In establishing ultimate right-of-way and the replacement of sections of our state highway routes, we are continually confronted with sections of highway which have been constructed and must be abandoned if correct grades and locations are to be obtained. We find that some of our division engineers develop their projects on the basis of sound engineering principles with due consideration of traffic development in the future while others are inclined to be governed largely by local conditions and present influences which are more or less expedients.

It is my intention in outlining the following policies that you shall all work along the same lines and when limits are set we expect you to do the best you reasonably can and not merely to meet these requirements. There will be exceptions to these limits necessarily, but in every case where the conditions set forth are not met I must have a complete explanation in order to justify approval.

For the purpose of outlining these policies, the highways will be divided into three classes as follows:

1. Highways carrying an average present daily traffic of 3000 or more vehicles when improved.
2. Highways carrying an average present daily traffic of less than 3000 vehicles or more than 500 vehicles per day on primary routes, or more than 1000 vehicles per day on other highways when improved.
3. Highways carrying less present traffic than indicated for Class 2 Highways above.

Width

Class 1 Highways. It is anticipated that this class of highway will require more than two 10-foot paved lanes and if practicable the shoulders shall be developed 10 feet in width on either side. High curbs shall not be placed on a highway which will not provide for at least three travel lanes plus minimum 8-foot parking lanes on either side. The width of parapets on bridges, or structures shall be not less than the width of graded roadway, excepting bridges more than 45 feet in length.

Class 2 Highways. The width of these highways shall be not less

*These instructions supersede earlier instructions. The change was made for 1929.

than two 9 or 10-foot traffic lanes as required, and if practicable the graded width of shoulders shall be from 8 to 10 feet in width on either side. High curbs shall not be constructed on such highways closer than will permit two moving traffic lanes and two parking lanes not less than 8 feet in width. The width of parapets on bridges, or structures, shall be not less than the width of graded roadway, excepting bridges more than 45 feet in length.

Class 3 Highways. The width of these highways shall be not less than two 9-foot traffic lanes and the graded width of shoulders shall be from 5 to 8 feet on either side as conditions warant. The width of structures between parapets shall be the full width of the graded roadway, if practicable, and in no case less than 22 feet between wheel guards, or curbs.

Grades

Class 1 Highways. A sincere effort shall be made to hold 7 per cent as the maximum grade, excepting on grade crossing elimination structures where the maximum grade shall be 5 per cent.

Class 2 Highways. A sincere effort shall be made to hold the maximum per cent of grade to 7 per cent, but an 8 per cent grade may be used without explanation. On grade crossing elimination structures the maximum grade shall be 5 per cent.

Class 3 Highways. The grade shall be held as low as economically practicable with due consideration to the importance of the highway when ultimately developed throughout its length. On grade crossing elimination structures the maximum grade shall be 6 per cent.

Alignment

Classes 1 and 2 Highways. A sincere effort shall be made to hold the degree of curvature to 4 degrees or less, and an explanation shall be given for the necessity of any curve of a greater degree. On grade crossing elimination structures the maximum curvature shall be 6 degrees.

Class 3 Highways. A sincere effort shall be made to keep the curvature to 6 degrees or less. On grade crossing elimination structures the maximum curvature shall be 8 degrees.

On all classes of highways, an effort shall be made to avoid the combinations of maximum curvature and grade. Due consideration must be given to the ultimate necessity of by-passing congested built-up sections, especially on Class 1 and Class 2 highways.

Sight Distance

Classes 1 and 2 Highways. Sight distance shall be not less than 400 feet.

Class 3 Highways. Sight distance shall be not less than 300 feet.

SAMUEL ECKELS, Chief Engineer.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS

C-1121

Harrisburg

Subject: Ultimate Right-of-Way Widths.

ALL DIVISION ENGINEERS
AND DISTRICT ENGINEERS:

The tentative ultimate right-of-way plan is approved for highway widths of 80 feet, 100 feet and 120 feet. Before any surveys are made, however, in built-up sections, the districts must submit information to this office showing the clear width between buildings, and no ultimate right-of-way surveys are to be made on these sections of highway before definite width is approved by this office.

It is expected there will be considerable variation from the widths on the ultimate right-of-way map in built-up sections where there would be considerable cost for the damages due ultimately to destroying the buildings or moving them back, unless the county commissioners are in accord with the proposed width of the ultimate right-of-way and are prepared to pay the damages.

In boroughs it must be understood that the Department of Highways has no authority to dictate or change the width of right-of-way or location of a street as laid out. You will, therefore, confer with the borough authorities concerning any ultimate right-of-way or relocations in boroughs, pointing out to them the desirability of cooperating in the laying out of an ultimate right-of-way. If the borough authorities will not agree to a greater width than the existing ordained width of the street, then there is no advantage in making a detailed survey through the borough and you will run out the center line and chain it in order to preserve the continuity of the stationing and no other work need be done in the borough.

A sincere effort must be made to continue the right-of-way surveys through the borough, even though the width must be somewhat restricted, and a report must be made to this office regarding such situation.

W. H. CONNELL,
Engineer Executive and Acting Secretary of Highways.

COMMONWEALTH OF PENNSYLANIA
DEPARTMENT OF HIGHWAYS

C-1082

Harrisburg

Subject: Right-of-way Data on Construction Drawings.

ALL DIVISION ENGINEERS
AND DISTRICT ENGINEERS:

The following procedure will be carried out on all drawings submitted for lettings.

All construction drawings for work on the state highway system must carry all the data necessary to show the present legal right-of-way, the required or construction right-of-way, and the proposed ultimate right-of-way. On all construction drawings off route all data necessary to show the present legal right-of-way and the required or construction right-of-way will be given.

Legal Right-of-Way

The legal right-of-way of a highway is the established width dedicated to public use by legislative enactment or by proper court proceedings, or in the absence of such, the width that has been used by the public for twenty-one years or more. In the latter case, this width must be determined by measurements between existing fences or monuments, or from physical conditions as noted upon the ground.

In cases where the legal width of right-of-way is known, the location of the center line of this legal width must be determined by measurements from existing fences or monuments, or where these markings do not exist, from the approximate center line of the traveled road. Where two well developed fence lines or monumented property lines are present, the center line of the legal right-of-way is considered as being midway between these lines, and the outer limits of the legal right-of-way are found by taking half of the legal right-of-way on either side of the center line so established. Where but one fence line or line of monuments is to be found, the center line is considered as being located from this line a distance equal to half of the legal right-of-way.

Where there are no well developed fence lines, monuments, or other conditions which would indicate the limits of the legal right-of-way, the exact center line of the approximate alignment of the traveled road is considered as the center line of the legal right-of-way, and the outer limits of the legal right-of-way are found by laying off half of the legal width on each side of the center line so established.

Where the legal width of right-of-way is not given by legislative enactment or by court records, or is not obtainable from monuments

on the ground, it will be determined as the width which has been used by the public for twenty-one years or more. It is important in determining this width, to include all land which has been presumably set aside for the public highway, and old fence lines, rows of trees, hedges or stone walls usually will define the width of the highway. In the absence of all such markers, a width must be determined which will at least include the traveled roadway and the side ditches.

On all construction drawings, the limits of the legal right-of-way as determined by one of the above outlined methods shall be shown in ink, using the conventional line adopted for property lines; that is, a dot and dash line. This line shall be marked on each sheet, "Present Right-of-Way as determined."

In all cases, construction drawings shall show under the general notes, the legal width of highway. If this legal width has been determined from records of court proceedings, it should be noted as follows:

"Legal Right of Way................................Feet
Road Docket No.........., Vol. No.........., Page No........
Court House at............................., Pennsylvania."

If the legal width has been determined by measurement from markers, etc., it should be noted as follows:

"Legal Right of Way................................Feet
No legal proceedings found
Width determined from markers, etc."

Where the width has been determined by measurements from markers, the District Engineer's letter of transmittal must show completely, but concisely, the character of markers from which width was determined, and the method used in the determination of the width.

Required Right-of-Way

The required right-of-way is the area necessary for construction which extends beyond the present legal limits of the highway, including the land necessary for cuts and fills and berm and side ditches. Required right-of-way lines must extend at least three feet beyond the slope line at the top of the cuts and bottom of the fills. Where berm ditches may be necessary, the required right-of-way line should extend at least ten feet beyond the slope line. The required right-of-way lines shall be shown upon the construction drawings in the manner outlined in either of the three following typical cases.

(1) Where the area required for construction purposes does not extend beyond the limits of the legal right-of-way established as before noted, obviously in this case the "Present Right-of-Way as

determined" and the required right-of-way are identical, and no required right-of-way lines would be shown.

(2) Where a portion of the area required for construction extends beyond the limits of the legal right-of-way established as before noted.

In such cases the required right-of-way area will be defined by a solid inked line parallel to the construction center line, with right angled offsets as required. This line shall be marked "Required Right-of-Way" and the offset distances shall be shown from the "Right-of Way Line as determined" to the "Required Right-of-Way" Line as above noted. The area defined by the above lines outside the legal right-of-way must be acquired, for construction purposes.

On the opposite side and at a distance equal to the legal width of the highway, (but in no case less than thirty-three feet), another line shall be shown in the same manner parallel to the construction center line with right angled offsets as required. This line shall be marked "Revised Right-of-Way Line," and the area between the "Revised Right-of-Way Line" and the "Right-of-Way Line as determined" shall be noted for vacation, unless in exceptional cases it should be retained for highway purposes subject to the provision that the total width of the right-of-way does not exceed 120 feet. These cases should be brought to the specific attention of the central office at the time construction plans are submitted by means of a letter setting forth all the facts and reasons for suggesting a variation from the usual rule.

(3) Where the area required for construction purposes lies entirely outside of the legal right-of-way established as before noted.

The area required for construction purposes shall be defined by two solid inked lines marked "Required Right-of-Way Line," which line shall be parallel to the construction center line with right angled offsets as required. The distance between these lines shall be equal to the width of the legal right-of-way as established on the adjacent sections of the old highway, (but in no case less than thirty-three feet), unless additional width is considered necessary. Should additional width be necessary, the total width of right-of-way must not exceed 120 feet, and the reasons for this widening of the right-of-way should be brought to the specific attention of the central office in the same manner as outlined under case 2.

Ultimate Right-of-Way

The ultimate right-of-way width is the width that will be required for highway purposes at some future time. Hereafter, in the preparation of construction drawings, the side lines of the ultimate right-of-way will be shown on the tracings sent to the Harrisburg office.

These side lines will be placed in soft pencil on the tracings, and the widths used in any particular case, unless otherwise fixed, will be those established by the approved tentative right-of-way establishment maps which have been distributed from this office.

Where it shall seem impracticable for any sufficient reason to use the established width of the maps referred to, the District Engineer will use and show a different width on the construction plans, and in that case he will accompany the transmittal of the tracings with a letter setting forth concisely, but comprehensively and clearly, his reasons for suggesting the variation from the width provided by the maps.

The use of these ultimate right-of-way widths—which generally are considerably greater than the old existing rights-of-way—suggests immediately the possibilities for improvements in alignment not practicable with the narrower widths of public right-of-way. Consequently consideration of this better alignment in the new right-of-way should be had in establishing the center lines for road improvement before they are finally fixed.

Again, in widening the rights-of-way, it can readily be seen that there is frequently no reason for extending the old right-of-way uniformly on both sides of the center line of the old roadway. In fact, property damages may often be reduced by widening wholly on the side where developments of the property are less valuable and at the same time equally good or even better alignment may thereby be had. However, it generally is undesirable (except in relocations) to fail to comprise in the wider new right-of-way all of the old right-of-way, though it is entirely possible that in some cases all of it may not be included. In those cases, special explanation will be made by the District Engineer in writing.

Normally, the center line of the ultimate right-of-way and of the new roadway, will coincide and be the same. Where they do not, the reasons for their failure to do so will be clearly set forth by the District Engineer in his letter of transmittal.

Following the established practice, in sending the drawings for the improvement of a road to the County Commissioners, their attention will be invited to both the right-of-way required for the actual work contemplated and the ultimate width proposed for legal establishment through the formal filing of ultimate right-of-way plans.

This advance notice given by the ultimate right-of-way side lines on the construction drawings may often be of benefit to the county authorities in enabling them to secure in advance or at one time all of the width immediately or ultimately to be required.

Under the laws the county authorities are responsible, on the filing of the construction drawings by the State, for providing the right-of-way needed for construction purposes. Their provision of the ultimate right-of-way is not their responsibility until the plans for the ultimate right-of-way and center line description thereof shall have been formally filed as provided by law, and a proper notice given them by the State to provide the ultimate right-of-way so recorded.

W. H. CONNELL,
Engineering Executive and
Acting Secretary of Highways.

APPENDIX B

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